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Solution of Naturally-Occurring Glasses in the
Geological Environment

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ABSTRACT

As part of a study to investigate the feasibility of putting nuclear wastes in glass containers and burying them on land or dumping them in the ocean, we have made a study of the amount of solution experienced by naturally occurring glasses from two land sites and thirty-four deep-sea sites. The glasses used in this study are microtektites from three strewn fields (Australasian, Ivory Coast, and North American) and from the Zhamanshin impact crater in southern Siberia. The microtektites range in age from 0.7 to 35 m.y. and they have a wide range in composition. The weight percent SiO_2 , for example, ranges from 44.8 to 81.7. Although several criteria for determining the amount of solution were considered, most of the conclusions are based on two criteria: 1) width of cracks, and 2) elevation of silica-rich inclusions above the adjacent microtektite surface. All the measurements were made on scanning electron microscope photomicrographs of the microtektites. The amount of solution was determined for about 170 microtektites; and measured amounts of solution range from 0.2 to at least 28 μm , but most are less than 5 μm . There appears to be no systematic relationship between age and amount of solution. This could be explained if solution ceases shortly after burial. Such a conclusion is supported by the study of microtektites recovered from agglutinated foraminifera tests which show normal amounts of solution that must have taken place before incorporation into the foraminifera tests, but no indication of solution after incorporation into the tests. Solution amounts are higher for microtektites in terrestrial settings than for microtektites in deep-sea environments. Within the marine environment there appears to be a tendency for the amount of solution to increase with decreasing water depth and with

increasing sedimentation rate. The amount of solution also varies with composition. The SiO_2 content seems to have the greatest influence with amount of solution increasing with decreasing SiO_2 . In the marine environment, for a given SiO_2 content, the amount of solution generally increases with increasing CaO and alkali content and perhaps with decreasing FeO and/or MgO content. In the terrestrial environment, however, the relationship between solution and composition appears to be reversed; thus, for a given SiO_2 content, the amount of solution seems to increase with increasing FeO, and perhaps MgO, and with decreasing Al_2O_3 , and perhaps CaO and alkali content.

INTRODUCTION

The safe disposal of high-level radioactive wastes from nuclear reactors is a major problem because of the danger to life which may arise if these substances were released into the environment. One suggestion is to bury the nuclear wastes in glass canisters (Frosch, 1977) or to fixate the nuclear wastes in oxide glasses (McElroy et al., 1972). Glasses can withstand high ambient temperatures better than plastics or concrete and they are more durable than metals, especially in saline solutions. Disposal of nuclear wastes in glass requires assurance that the glass will survive for a time on the order of 10^6 years. Since no man-made glasses have been around that long, it was proposed to study various naturally-occurring glasses in order to determine their durability with time in various natural environments.

The purpose of the proposed research was to study the amount of solution experienced by naturally-occurring glasses in various geological environments. Microtektites were used in this study for several reasons:

- 1) They have a wide range in ages -- i.e., 0.7 to 35 m.y.
- 2) They were deposited in a wide range of geological environments.

Most of the microtektites used in this study came from a wide range of deep-sea environments, but two groups came from land areas. One group of particles came from Zhamanshin crater. These glasses, called micro-irghizites, have compositions and ages similar to the Australasian microtektites found in deep-sea deposits. The second group consists of North American microtektites deposited in a deep-sea environment, but which now

occur on land in Barbados (Table 1).

3) They have a wide range in composition. For example, the SiO_2 content of the microtektites used in this study ranges from 44.8 to 81.7%.

4) Previous work has indicated several criteria that can be used to estimate solution amounts. These criteria will be discussed later in the report.

5) The microtektites were already available for the study in a collection at the University of Delaware.

The present collection at the University of Delaware contains tens of thousands of microtektites ranging in age from 0.7 to 35 m.y., with a wide range in composition (Cassidy et al., 1969; Glass, 1970; Glass, 1972; Glass and Zwart, 1979a and b), and are from a wide range of deep-sea environments (e.g., physiographic province, water depth, sediment type). Thus it is possible to correlate the amount of solution with age, chemistry, and environment of deposition. In addition, microtektites found on land with similar ages and compositions to those found in deep-sea deposits offer a chance to compare solution in terrestrial versus deep-sea environments.

SAMPLES

Microtektites belonging to the Australasian strewnfield have been found in deep-sea deposits in the Indian Ocean, Philippine Sea, and western equatorial Pacific Ocean (Glass et al., 1979). Ivory Coast micro-

tektites have been found in the eastern equatorial Atlantic Ocean (Glass and Zwart, 1979a), and North American microtektites have been found in the Caribbean Sea, Gulf of Mexico, equatorial Pacific Ocean and eastern Indian Ocean (Glass and Zwart, 1979b; Glass and Crosbie, 1982). The North American microtektites have been found in one piston core and cores from nine Deep Sea Drilling Project (DSDP) sites. Australasian microtektites have been found in thirty piston cores and Ivory Coast microtektites in five. For this study, Australasian microtektites were selected from twenty-one cores, Ivory Coast microtektites from five cores, and North American from one piston core and cores from seven DSDP sites (Table 2). The cores were taken in water depths ranging from 1793 to 5323 meters. The Australasian microtektites were found in a wide range of sediment types including calcareous and siliceous oozes, calcareous and siliceous lutites, red clay and hemipelagic sediments (Table 2). The Ivory Coast microtektites were found mostly in calcareous oozes or calcareous lutites. The North American microtektites were found in siliceous or calcareous oozes. Calculated sediment accumulation rates range from 0.12 to 1.68 cm/1000 yrs.

The Australasian, Ivory Coast, and North American (Table 1) microtektites were formed and fell on the ocean floor 0.7, 1, and 35 m.y. ago, respectively.

The micro-irghizites were obtained from P. V. Florensky, at the Academy of Sciences, USSR, via T. Cobleigh, Johnson Space Center, and K. Fredriksson, at the U.S. National Museum, Washington, D.C. They apparently were recovered from a stream deposit in or near the Zhamanshin structure. T. Cobleigh recovered the micro-irghizites by pouring small amounts of sample at one corner of a large sloping board with a glass surface and tapping. The spherical micro-irghizites rolled down the board and were collected at the bottom. The micro-irghizites have compositions and ages similar to the Australasian microtektites (Florensky, 1975; Glass, 1979; Taylor and McLennan, 1979; Florensky and Dabizha, 1980).

The North American microtektites from Barbados were obtained from W. R. Riedel, Scripps Institution of Oceanography. These microtektites were originally deposited in deep-sea sediments which were subsequently tectonically uplifted above sea level, probably less than 0.5 m.y. ago (W. R. Riedel, personal communication, 1983).

METHODS

Procedures. The entire collection of tens of thousands of microtektites was searched for microtektites that showed evidence of solution using a binocular microscope with up to 50X magnification. A total of 307 microtektites were selected for study. In addition, 16 North American microtektites from Barbados and 28 micro-irghizites were selected. The samples were mounted and coated for scanning electron microscope (SEM) study. Photomicrographs were taken of 53 Australasian microtektites, 38 Ivory Coast microtektites, 80 North American microtektites, 21 micro-irghizites, and 16 Barbados microtektites. Measurements of the amount of solution were made on the photomicrographs using the criteria discussed below.

After SEM studies, the microtektites were removed from the SEM stubs and remounted in epoxy on 1" diameter glass discs, ground down to expose a flat interior surface, polished, and then coated with carbon. The major element compositions were determined using an energy dispersive x-ray analyzer (EDAX) in combination with the scanning electron microscope. The analyses were made at 20 KV, 45° tilt angle, 30.2° take-off angle, and 2000 counts per second for 200 seconds. Glasses, with tektite compositions, made by Corning Glass Company and analyzed by the United States Geological Survey were used as standards and mounted on each disc with the microtektites. The data were corrected for background, absorption, atomic number

effect and fluorescence using a computer program (EDIT/7.Ep) by EDAX International, Inc. A nonstandard computer program was used and the standards were analyzed as unknowns. All the analyses were converted to oxide percents, normalized using the same standard, and recalculated to total 99.6%.

Criteria Used to Estimate the Amount of Solution. Several criteria have been used to estimate the amount of solution that the microtektites have undergone.

1) Some microtektites have cracks that have been widened by solution (Fig. 1). If it is assumed that the cracks formed at the time of fall, or shortly thereafter, then the width of the crack is twice the amount of surface solution. Once the microtektite is buried in the sediment, there appears to be no reason for it to break, except perhaps due to stresses generated by hydration. At any rate, the cracks can be used to determine the minimum amount of solution.

2) Microtektites, like tektites, contain silica-rich inclusions (including lechatelierite). In some cases, the inclusions formed at the surface of the microtektite with their outer surface flush with the surface of the microtektite. Differential solution has resulted in the inclusion standing above the surrounding surface, producing a protrusion (Fig. 2). We believe that the top of these protrusions represents the original outer surface (or close to it) of the microtektite and that the relief between the top of the protrusion and the adjacent microtektite surface indicates the amount of solution that the microtektite glass has experienced. Two observations support this conclusion. First, where a microtektite has two or more silica-rich protrusions, their outer surfaces are often concentric

with the present microtektite surface and are generally elevated approximately the same distance above the adjacent microtektite surface. Second, when a microtektite with silica-rich protrusions is broken and cracked, the cracks are twice as wide as the protrusions are high (Fig. 3). The SiO_2 -rich protrusions have a variety of shapes (Fig. 2), but all have a circular outer surface that is concentric with the surface of the microtektite. With only a minor amount of solution, the SiO_2 -rich area is slightly elevated above the microtektite surface (Fig. 4). With greater solution, more of the protrusion is exposed and the general shape of the protrusion becomes more evident (Fig. 4). With still further solution, the SiO_2 -rich particle rests on top of a pedestal of microtektite glass which was protected from solution by the overlying SiO_2 -rich particle (Fig. 4). Further solution may completely undermine the SiO_2 -rich particle and free it from the microtektite, leaving a conical-shape protrusion of microtektite glass (Fig. 4). Measurements of such features would only indicate the minimum amount of solution that has occurred.

3) U-shaped grooves (Fig. 5) occur on the surface of some microtektites especially those from the Ivory Coast strewnfield. The U-shaped grooves were apparently produced by solution of thermal cracks on the surface of the microtektites (Glass, 1974). Similar U-shaped grooves, except for their size, are found on some tektites, particularly billitonites (Baker, 1959). Chapman et al. (1967) used the widths of the U-shaped grooves on tektites to determine the amount of solution they have experienced. We attempted to use the U-shaped grooves to estimate the amount of solution experienced by the microtektites assuming that the amount of solution equals $1/2$ the width of the grooves.

4) Studies of microtektites in agglutinated foraminifera tests (Fig. 6) have also been used to determine the amount of solution. This criterion has only been used to attempt to determine the amount of solution experienced by microtektites found in agglutinated foraminifera tests. One method is to compare the exposed surfaces with those embedded in the test. The second method is to determine the distance between two closely-spaced microtektites in a test. This method gives the maximum amount of solution for the two microtektites combined.

5) A fifth criterion is based on exposed bubble cavities (Fig. 7). If it is assumed that an exposed bubble cavity was originally enclosed by glass, then the amount of solution required to expose it to the degree that it is presently exposed can be determined. Again, this only indicates the minimum amount of solution since it is not known how far below the surface the bubble originally formed.

The most useful and reliable criteria appear to be the cracks and silica-rich protrusions. Microtektites with cracks and/or silica-rich protrusions were found at nearly all the sites, and when a microtektite had both features, they both generally indicated the same amount of solution. The U-shaped grooves, on the other hand, are with few exceptions found only on the Ivory Coast microtektites. Where present, the U-shaped grooves often indicate several times the amount of solution indicated by cracks or silica-rich protrusions. (Note: Although U-shaped grooves and cracks can grade into each other, we distinguish U-shaped grooves based on their rounded or concave bottoms and width-to-depth ratios greater than one. On the other hand, cracks, as used in this study, are much deeper than they are wide and generally have flat bottoms - see figures 1 and 5). Because the U-shaped grooves

generally indicate more solution than the cracks or silica-rich protrusions, and since the U-shaped grooves are essentially confined to the Ivory Coast microtektites, we have not used data from the U-shaped grooves in our conclusions concerning the amount of solution that the microtektites have experienced. The criteria using agglutinated foraminifera tests and exposed bubble cavities can only be used in a limited number of cases and neither method yields quantitative data. Thus most of our conclusions are based on solution estimates using silica-rich protrusions and cracks.

RESULTS

Measured amounts of solution range from 0.2 to 28 μm , or up to 93 μm if the data from the U-shaped grooves are used (Table 3). When both cracks and silica-rich protrusions were present, the two features often indicated the same amount of solution. However, they do not always agree. In most cases when the two criteria do not agree, the cracks indicate less (generally about 1/2) the amount of solution as indicated by the silica-rich protrusions. Generally when the cracks indicate less solution than the silica-rich protrusions, the cracks are merely surface cracks. Deep cracks that extend a significant distance ($> 1/4$ the radius) into the microtektite generally indicate solution amounts in agreement with the silica-rich protrusions. Thus most of the questionable solution amounts given in Table 3 are based on surface cracks which probably indicate only minimum amounts of solution.

Major element analyses were obtained for 46 of the Australasian microtektites, 34 of the Ivory Coast microtektites, and 74 of the North American microtektites for which we obtained solution measurements (Table 4). SiO_2 contents range from 44.8 to 76.2, 62.1 to 70.0, and 59.0-81.7 for the

Australasian, Ivory Coast and North American microtektites, respectively. Most have compositions similar to previously published analyses for microtektites from these strewn fields, but some have unusual or unique compositions.

DISCUSSION

Limitations

A discussion of some of the limitations of this study is in order before proceeding to a discussion of the results. First, it should be noted that although most of the microtektites showed some evidence of corrosion, only a small percentage of the microtektites in the collection had obvious features (e.g., cracks or silica-rich protrusions) that could be used to quantify the amount of solution that they have undergone. Secondly, since we only see the end product and have no idea what the original population was like, we have no way of knowing how many microtektites may have been completely removed by solution. Complete dissolution may be the reason why we don't find any microtektites at some sites where otherwise we would have expected them. Finally, we note that some of the microtektites show no signs of corrosion. In these cases, we do not know if the microtektites have not experienced any solution, or if they have undergone uniform solution and have no features present to indicate how much solution they have experienced. Thus the data presented in this report are limited to a small percentage of unique specimens. Nevertheless, we were able to obtain solution amounts for about 170 specimens having a great range in age and composition, and from a rather wide range in depositional environments (Tables 1, 2 and 4).

Relationship Between Composition and Amount of Solution

The microtektites from a given site show a general decrease in amount of solution with increasing SiO_2 content (Fig. 8), and at most of the deep-sea sites microtektites with greater than 70% SiO_2 show less than 5 μm of solution. Furthermore, the silica-rich protrusions, which are often nearly pure SiO_2 , have apparently undergone little or no solution. This is supported by the observation that when microtektites have both cracks and silica-rich protrusions, the widths of the cracks are almost never greater than twice the heights of the silica-rich protrusions (Table 3). This is further support for the inverse relationship between solution and SiO_2 content.

In all of the strewn fields, however, there are examples of microtektites from a given site with similar SiO_2 contents, but with large differences in amount of solution (Table 5). In some of these cases, the microtektites have similar major oxide compositions and, therefore, the amount of solution does not appear to be related to differences in major oxide compositions. By comparing the compositions of microtektites from a given site with similar SiO_2 contents but with different amounts of solution, we found some possible relationships between amount of solution and major oxide composition other than SiO_2 . In general, the amount of solution for Australasian microtektites, from a given site with similar SiO_2 contents, increases with increasing CaO and K_2O and possibly with decreasing FeO and Al_2O_3 contents. The amount of solution for the Ivory Coast microtektites appears to increase with increasing alkali content and with decreasing TiO_2 (and

possibly FeO) contents, North American microtektites from deep-sea sites show increasing solution with increasing Al_2O_3 , CaO, and Na_2O contents and decreasing MgO contents. In general, then, the amount of solution appears to increase with decreasing SiO_2 content, and for a given SiO_2 content the amount of solution generally increases with increasing CaO and alkali contents and perhaps with decreasing FeO and/or MgO contents. These generalizations are, however, based on only a few examples and there are many exceptions.

The microtektites from the two land sites (i.e., the micro-irghizites and the Barbados microtektites) also tend to show increasing amounts of solution with decreasing SiO_2 contents (Figs. 9 and 10); but again, there is a great deal of scatter. The micro-irghizites, like the Australasian microtektites, tend to show increasing amounts of solution with decreasing Al_2O_3 contents for a given SiO_2 content. However, in contrast to the Australasian microtektites, the micro-irghizites show increasing amounts of solution with increasing FeO (and perhaps MgO) and decreasing CaO and alkali contents. Likewise the North American microtektites found on Barbados show different relationships between amount of solution and major oxide contents for a given SiO_2 content as compared to North American microtektites from deep-sea sites. In contrast to the North American microtektites from deep-sea sites, the North American microtektites from Barbados show increasing solution with increasing MgO (and FeO) and decreasing Al_2O_3 (and perhaps CaO and alkali) contents. Thus it appears that differences in composition, other than SiO_2 content, have different effects on amount of solution in terrestrial versus deep-sea environments.

The above generalizations concerning the relationship between composition and solution are valid only if there has been no addition or subtraction of ions to or from the glass. If leaching or cation substitution has taken place, then it must have affected each microtektite entirely, since previous studies have not found any systematic variations in composition from the core to the outside.

Relationship Between Environment and Amount of Solution

Although there is a great deal of scatter in the data, microtektites from a given deep-sea site often show different amounts of solution when compared with microtektites with similar SiO_2 contents from other deep-sea sites within the same strewn field (Figs. 11-13; Table 6). In the Australasian strewn field, microtektites from V16-70 seem to show the least solution and microtektites from E49-4 seem to show the most, with microtektites from V20-138 showing intermediate amounts. In the Ivory Coast strewn field, microtektites from V27-239 and K9-57 seem to show the least solution and microtektites from V19-300, V19-297, and K9-56 seem to show increasing amounts of solution, respectively. In the North American strewn field, microtektites from DSDP site 149 and 216 and RC9-58 show the least amount of solution and microtektites from DSDP sites 292 and 94 show the most. However, we only have data for two to four microtektites from some of the above cores.

There appears to be no correlation between average amount of solution and sediment type (Table 6), but there does appear to be a tendency for the amount of solution to increase with decreasing water depth and with increasing sedimentation rate (Table 6; Figs. 14 and 15). There are,

however, several exceptions to these two generalizations. Differences in composition of the microtektites between sites may explain some of the exceptions. On the other hand, differences in composition of microtektites between sites may explain most, if not all, of the differences in solution between sites. Indeed, the differences in compositions of microtektites between sites are in the direction needed to explain the differences in amounts of solution as discussed in the previous section. Furthermore, the observed relationships between amount of solution and water depth and sedimentation rate are opposite to what we would have expected. The solution of biogenic carbonate, and to a lesser extent biogenic opaline material, increases with increasing depth. And, in general, in areas of pelagic sedimentation the rate of sediment accumulation decreases with increasing depth and we would expect solution to decrease with increasing sedimentation rate for reasons that will be discussed in the next section.

Although there is some overlap, the micro-irghizites, which have similar age and compositions as the Australasian microtektites, generally have about two to three times as much solution for a given SiO_2 content as the Australasian microtektites (Fig. 9; Table 7). Likewise, the North American microtektites found on Barbados generally show more solution than the North American microtektites (Fig. 10; Table 7). Since the micro-irghizites and Barbados microtektites are similar in age and composition to the Australasian and deep-sea North American microtektites, respectively, we assume that the greater amount of solution of the micro-irghizites and Barbados microtektites is due to their occurrence in a terrestrial as opposed to a deep-sea environment.

Relationship Between Age and Amount of Solution

It appears that the 35 m.y. old North American microtektites have on the average undergone less solution than either the 0.7 m.y. old Australasian microtektites or the ~1 m.y. old Ivory Coast microtektites (Table 7). This is surprising since the North American microtektites are ~35 to ~50 times older than the Ivory Coast and Australasian microtektites, respectively. A possible explanation is that solution slows down drastically or ceases shortly after burial (Barnes, 1973, written communication). A study of microtektites found in agglutinated Foraminifera tests seems to support this.

Microtektites are common components of tests of agglutinated Foraminifera found in sediments containing or adjacent to the North American microtektite layer at several deep-sea sites (RC9-58, DSDP 94, DSDP 149, DSDP 166). Since the agglutinated Foraminifera are bottom dwellers and not burrowers, the microtektites must have been incorporated in their tests before burial. Based on the estimated sediment accumulation rates (Table 2), a 500 μ m diameter microtektite would be buried in less than 500 yrs even at the sites with the lowest sediment accumulation rate. Thus the microtektites must have been incorporated into the foraminifera test shortly after deposition. In the beginning of the study, we hypothesized that the portion of each microtektite enclosed in the test must have been protected from solution; therefore, by removing the microtektites from the tests, we could determine the amount of solution by determining the difference in relief between the exposed and covered (or protected) surfaces. We were not able to see any differences between the exposed and enclosed surfaces (see, for example, Fig. 6). The microtektites, however, have undergone solution

etching, and in a few cases, microtektites in foraminifera tests had silica-rich protrusions that indicated comparable amounts of solution as microtektites not found in foraminifera tests. The microtektites were still tightly bound to the test so that the observed solution could not have taken place after the microtektites were incorporated into the tests. If solution had taken place uniformly around the entire surface of the microtektites, then they would no longer be tightly bound to the adjacent test material; and if solution had only affected the exposed surface of the microtektite, then there should have been an obvious difference in relief between the exposed and enclosed surfaces -- and there is not. Thus the observed solution must have taken place before incorporation into the foraminifera tests. Furthermore, since the microtektites in the foraminifera tests show as much solution as microtektites not in the tests (based on only a few measurements), this implies that all of the microtektites underwent solution immediately upon deposition and that solution essentially ceased on or shortly after burial. This study, then, supports Barnes' (1973, written communication) suggestion that solution ceases shortly after burial and it seems to explain why 35 m.y. microtektites don't show any more solution than 0.7 m.y. old microtektites. There appears to be at least one set of data that is not consistent with this hypothesis.

If solution ceases upon burial, or shortly thereafter, we would expect microtektites deposited in areas of rapid sedimentation rate to be buried quickly and thus to show low amounts of solution. Conversely

in areas of slow sedimentation rate the microtektites would be exposed to solution for longer periods of time and should, therefore, show greater amounts of solution. As previously discussed, however, there appears to be no clear relationship between sediment accumulation rate and amount of solution (Fig. 15). If there is any correlation at all, it appears to be one of increasing solution with increasing sediment accumulation rate. We make here a distinction between sedimentation rate and sediment accumulation rate. Sedimentation rate is a measure of how rapidly sediment is being deposited in an area. Later processes, such as erosion by bottom currents or slumping, may add or take away sediment from the area. The accumulation rate is a measure of the amount of sediment that survives in an area per unit time. Thus we could have an area with a high sedimentation rate which, because of periodic slumping, is an area of low sediment accumulation. The rates given in this report are sediment accumulation rates, and for most of the sites we have no idea what the actual sedimentation rates were at the time of microtektite deposition. This might help explain the lack of an inverse correlation between sediment accumulation rate and amount of solution. Another possible complication is sediment reworking by burrowing organisms -- i.e., bioturbation.

The rate of vertical mixing of sediments can vary from place to place on the ocean floor. Several attempts have been made to quantify the amount of reworking at different sites using the vertical distribution of microtektites (Glass, 1969; Guinasso and Schink, 1975; Ruddiman et al., 1980; Perrone, 1980; Officer and Lynch, 1982). Unfortunately, the rate of vertical

mixing (diffusion coefficient) in $\text{cm}^2/10^3 \text{ yr}$ has only been determined for three of the important cores used in this study and the authors do not agree in either relative or absolute terms. Thus we cannot use that data in this study.

CONCLUSION

We have measured solution amounts for about 170 microtektites having a large range in age (0.7 to 35 m.y), composition (e.g., 44.8 to 81.7% SiO_2), and environments. Measured amounts of solution range from 0.2 to at least 28 μm , but most are less than 5 μm . We can make the following tentative generalizations:

1) Most of the observed solution took place before the deep-sea microtektites were buried. Solution appears to essentially stop upon burial. Therefore, there is no systematic relationship between age and amount of solution.

2) Solution amounts are higher for microtektites in terrestrial settings than for microtektites in deep-sea environments.

3) Within the marine environment there appears to be a tendency for the amount of solution to increase with decreasing water depth and with increasing sedimentation rate.

4) Solution varies inversely with SiO_2 content.

5) In the marine environment for a given SiO_2 content the amount of solution generally increases with increasing CaO and alkali contents and perhaps with decreasing FeO and/or MgO contents. In the terrestrial environments, however, the relationship between solution and composition appears to be reversed. For a given SiO_2 content, the amount of solution seems to

increase with increasing FeO, and perhaps MgO, and with decreasing Al_2O_3 , and perhaps CaO and alkalis.

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Table 1. Samples used in this study

Samples	Age (m.y.)	Environment	No. of measurements
Australasian Microtektites	0.7	Deep-Sea	51
Micro-irghizites	~1	Continental	14
Ivory Coast Microtektites	~1	Deep-Sea	25
North American Microtektites	35	Deep-Sea	66
North American Microtektites (from Barbados)	35	Deep-Sea originally (presently continental)	14

Table 2. Cores used in this study

Core	Water Depth (m)	Sed. Rate (cm/1000 yrs) ⁺	Sediment Type	No. of Solution Measurements
Australasian				
E45-74	3804	0.89	Sil. ooze (Rad.)	1
E45-89	4605	0.56	Cal. ooze (foram.)	1
E49-4	3568	(0.21)	Cal. ooze (foram. ooze w/sil. components)	5
E49-51	4230	0.41	Cal. ooze (nanno ooze w/forams & rads.)	1
LSDH-23G	4910	-	Cal. ooze (foram.)	2
MSN-48G	4996	-	Sil. ooze	2
RC9-142	4188	0.49	Cal. lutite (foram.)	3
RC9-143	4285	0.51	Cal. lutite	2
RC12-327	4326	0.90	Cal. lutite (foram marl)	1
RC12-328	3018	1.12	Cal. ooze (foram. chalk ooze)	1
V16-70	4649	0.22	Cal. lutite (foram)	3
V16-76	5310	(1.51)?	Red clay	2
V19-153	5258	0.75	hemipelagic? (greenish-tan lutite)	2
V19-169	4957	0.34	Red clay	3
V19-171	4904	0.50	hemipelagic (brownish-grey mud)	1
V20-138	4141	0.46	hemipelagic (Y-Br to olive-grey lutite)	11
V20-184	4883	1.04	Red clay	1
V28-238	3120	1.71	Cal. ooze (foram chalk)	1
V28-239	3490	1.03	Cal. ooze (foram)	5
V29-39	5082	0.16	Sil. lutite (Rad.)	3
V29-40	5323	0.51	Sil. lutite (Rad.)	1
Total				52
Ivory Coast				
K9-56	4687	1.68	hemipelagic (brownish-grey lutite)	7
K9-57	4479	1.59	Cal. lutite (?) (foram lutite?)	3
V19-297	4020	0.71	Cal. lutite (foram)	6
V19-300	4152	0.84	Cal. lutite (foram)	2
V27-239	4346	1.02	Cal. ooze (foram)	7
Total				25

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Table 2. Cores used in this study (continued)

Core	Water Depth (m)	Sed. Rate (cm/1000 yrs) ⁺	Sediment Type	No. of Solution Measurements
North American				
RC9-58	3456	-	Sil. ooze (Rad w/cal. components)	27
DSDP 70A	5059	0.12	Sil. ooze (Rad)	1
DSDP 94	1793	1.10	Cal. ooze (nanno chalk)	12
DSDP 149	3972	0.27	Sil. ooze (Rad w/cal. components)	13
DSDP 166	4962	0.50	Sil. ooze (Rad)	1
DSDP 167	3166	~0.90	Cal. ooze (?) (Rad. nanno chalk)	1
DSDP 216	2262	0.25	Cal. ooze (Nanno chalk)	6
DSDP 292	2943	1.20	Cal. ooze (Nanno chalk)	5
Total				66
Grand Total				143

⁺ - Sediment accumulation rates for the Australasian and Ivory Coast microtektite-bearing cores based on paleomagnetism. Sediment accumulation rates for the North American microtektite-bearing cores based on biostratigraphy and were taken from the Initial Reports of the Deep Sea Drilling Project

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Table 3. Solution measurements

Sample ¹	Number ²	%SiO ₂ ³	Amount of Solution (μm)			Preferred Value ⁶
			Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	
Australasian Microtektites						
E45-74	1-4b	56.7	9.3			9.3
E45-89-1	8-1a	69.0	11.7			11.7
E45-89-2	8-1b	53.6			23	?
E49-4-1	1-6d	53.5	9.1			9.1*
E49-4-2	1-6b	64.8(?)	4.6			4.6
E49-4-3	1-6c	69.4(?)	6.2			6.2(?)
E49-4-4	1-7	72.2	3.8			3.9*
E49-4-5	1-8	69.6	3.6-5.0	3.9		5.*
E49-51-2	2-1a	4.8	4.3-4.8			4.4*
LSDH-23G-1	4-7a	58.7	5.0			5.
LSDH-23G-2	4-7b	61.7	14.8			15.
MSN-48G-1	4-8b	61.1	4.5-9.2			9.
MSN-48G-2	4-8c	69.8		1.4		1.4(?)
RC9-142-1	2-3	61.2	3.8-4.1			4.3
RC9-142-2	2-4a	62.3	12.0			12.*
RC9-142-3	2-4b	58.2	14-15			15.*
RC9-143-1	2-5b	72.0		1.7-2.1		2.1(?)
RC9-143-3	2-5c	73.9	5.1	2.3(?)		5.1
RC12-327	2-6	63.3	6.0-8.0			8.
RC12-328	2-7	56.2	<0.2-3.8			?
V16-70-1	2-8a	59.2	11.0			11.*
V16-70-2	2-8b	65.8		0.9		0.9(?)
V16-70-3	2-8c	63.5		2.9-3.6		3. (?)
V16-76-1	3-1a	70.2		0.3-0.4		0.4(?)
V16-76-2	3-1b	56.4		3.2		3.2(?)
V19-153-1	3-2d	54.4		0.9-1.4		1.4(?)
V19-153-Br-1	3-3b(?)	54.2(?)		1.6-2.0		2. (?)
V19-169-1	3-4a	65.5		0.8		0.8(?)
V19-169-2	3-4b	-		2.4		2.4(?)

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Table 3. Solution measurements (continued)

Sample ¹	Number ²	ZSiO ₂ ³	Amount of Solution (μm)			Preferred Value ⁶
			Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	
V19-169-3	3-4c	71.0		1.7		1.7(?)
V19-171-1	3-5a	-		1.3		1.3(?)
V20-138	3-6d	64.6		(0.73-1.8)		1.8(?)
V20-138-1	3-6f	63.1	8-10			9. *
V20-138-3	3-6c	76.2		0.2-0.6		0.6(?)
V20-138-4	3-6e	63.2				8.5*
V20-138-5	3-6a	-	6.9-8.5			6. *
V20-138-6	3-7d	66.7	4.2-6.5			1.8*
V20-138-7	3-7a	64.4	1.3-1.8			5.
V20-138-8	3-7b	67.2	~5	2.6		4.8(?)
V20-138-9	3-7c	68.3	4.8	(1.9-2.1)		0.6(?)
V20-138-10	3-8a	66.0	3.8-4.2	0.6		4. *
V20-138-11	3-8b	68.9	2.0-2.6	~1.6		2.6*
V20-184	4-1	56.5	14(?)	1.1		14. (?)
V28-238	4-2	65.8		1.1.4		1.4(?)
V28-239-1	4-3e	-	2.5-3.5			3.5*
V28-239-2	4-3c	55.2	12-16			16. *
V28-239-3	4-3a	56.9	6.5			6.5(?)
V28-239-4	4-3b	56.8	4.0-6.5			6.5
V28-239-5	4-3d	55.6	~11.8(?)			11.8(?)
V29-39-1	4-4a	-		~5		5. *
V29-39-2	4-4b	-	~1.8-2.6			1.8(?)
V29-39-3	4-5	-	0.8-1.4			1.4(?)
V29-40	4-6	64.3		~0.4		0.4(?)
Ivory Coast Microtektites						
K9-56-1	5-1a	67.8	18			18. (?)
K9-56-2	5-1d	65.7	18			18. (?)
K9-56-3	5-1b	63.9	18			18. (?)
K9-56-5	5-1c	67.8	11.6			~12. (?)

Table 3. Solution measurements (continued)

Sample ¹	Number ²	%SiO ₂ ³	Amount of Solution (μm)			Preferred Value ⁶
			Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	
K9-56-6	6-1a	65.0			~93	?
K9-56-7	6-1b	68.0			~46	?
K9-56-10	6-5a	68.5			~42	?
K9-56-11	8-2b	67.9			~40	?
K9-56-12	8-2a	67.6			~34	?
K9-56-13	8-3	69.4	16-17	~14		17. *
K9-56-14	8-4	68.0			~41	?
K9-56-15	8-5	68.5	16			16. *
K9-56-16	8-6a	66.9			~43	?
K9-56-26	10-8a	67.0	16	15.5		16. *
K9-56-27	10-8c	67.3		35(?)		35. (?)
K9-57-1	5-2e	62.2	37(?)			37. (?)
K9-57-2	5-2c	65.0	34		19	?
K9-57-4	5-2d	67.2	16-21(?)			?
K9-57-6	5-3a	66.8	1.6-2.2			~2.
K9-57-7	5-3b	64.4	2.5-3.9(?)	~1.4		~3.5
K9-57-8	10-7f	65.0	9-15			15. (?)
V19-297-1	5-5b	67.4	5.1-9.5			?
V19-297-3	5-6c	69.0	3.8-4.6			4.6*
V19-297-4	5-7a	67.0	13-19			18. *
V19-297-5	5-7b	66.3	16-25			25.
V19-297-6	5-8a	66.4		13.4		~13.
V19-297-7	10-7c	66.4	7.6			7.6
V19-297-8	10-7b	-	10.8			10.8
V19-300-1	10-7d	64.4	~11			11. *
V19-300-2	10-7e	56.1	7.4			7.4
V27-239-1	5-4d	69.5	1.2-1.6	0.28		?
V27-239-2	5-4b	62.1	5-6			~6.
V27-239-3	5-4c	65.2	~1.3	1.2-1.6		1.6*
V27-239-4	5-4a	70.0	0.8-1.0	~0.7		0.9*

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Table 3. Solution measurements (continued)

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Amount of Solution (µm)						
Sample ¹	Number ²	%SiO ₂ ³	Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	Preferred Value ⁶
V27-239-5	5-4e	68.3	0.9-1.1	0.7		~1.
V27-239-6	6-6b	65.6	1.9-2.1	1.7		2. *
V27-239-7	6-6a	65.1	0.8			0.8
V27-239-8	6-7	68.0	1	0.65		~1.
North American Microtektites						
RC9-58	10-1b	67.0	(~1.1)			?
RC9-58-1	7-1	70.1	20-28	~15		?
RC9-58-2	7-2a	75.0	2.4	0.54		2.4(?)
RC9-58-3	7-2c	72.4	~40(?)			?
RC9-58-7	7-5a	75.2		~0.5		~0.5(?)
RC9-58-8	7-5b	64.2	1.4	~0.25		1.4
RC9-58-9	7-6a	65.1	24-28	(0.25-1.0)		?
RC9-58-10	7-6c	67.0		0.4		?
RC9-58-11	7-7b	64.6	~28			28. (?)
RC9-58-14	8-8b	85.6		0.7		0.7(?)
RC9-58-15	8-6b	79.3		1.4		1.4
RC9-58-16	8-7a	64.8	28.7			~29.
RC9-58-17	8-7c	77.4		1.3		~1.3(?)
RC9-58-18	9-1a	75.2		1.5		?
RC9-58-19	9-1c	78.9		1.3		1.3(?)
RC9-58-20	9-3b	67.5	<1(?)			<1. (?)
RC9-58-21	9-4a	79.6		0.5-1.2		~1. (?)
RC9-58-22	9-6a	64.1	4-10			~10.
RC9-58-23	9-7c	73.9(?)				~1. (?)
RC9-58-24	9-7a	80.2		1.1		~0.2
RC9-58-25	9-8a	77.1		0.2		0.9
RC9-58-26	10-1a	65.4		0.9		~10.
RC9-58-27	10-1c	64.5	0.47	9.8		~0.5

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Table 3. Solution measurements (continued)

Sample ¹	Number ²	%SiO ₂ ³	Amount of Solution (μm)			Preferred Value ⁶
			Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	
RC9-58-28	10-2a	76.1		0.29		~0.3(?)
RC9-58-29	10-3a	77.2		0.16		~0.2(?)
RC9-58-30	10-4a	61.4(?)	2.5			~2.5
RC9-58-31	10-4b	70.8-74.9	1.0			~1.
RC9-58-34	11-1a	74.8		~9		?
RC9-58-36	11-2c	73.4	11.3-12.8			~12.
RC9-58-37	11-2b	65.7	4.6			4.6*
RC9-58-38	11-2a	66.8(?)	3.8-4.5			4.5
RC9-58-39	11-3a	64.2	5.6-6.7			6.7
RC9-58-40	11-4a	80.6		0.4		~0.4
RC9-58-41	11-4b	63.9		3.2		3.2*
DSDP 70A	13-1	61.0	7.1			~7.
DSDP 94	11-8b	~73.5		(1.0)		~1. (?)
DSDP 94-1	11-5a	70.9		0.35-0.39		~0.4(?)
DSDP 94-2	11-5b	74.1		0.27		~0.27
DSDP 94-3	11-5c	81.4		4.2-6.3		~6.
DSDP 94-4	11-6a	75.4		0.62		~0.6(?)
DSDP 94-5	11-6b	77.7		0.43		?
DSDP 94-6	11-6c	77.7-78.7		0.39		~0.4(?)
DSDP 94-7	11-7c	79.3		1.71		1.7
DSDP 94-8	11-7a	75.8		6.5(?)		?
DSDP 94-9	11-7b	77.2	6.6-8.1(?)			~7.
DSDP 94-10	11-7c	77.3	14			14.0
DSDP 94-11	11-7d	81.7	10-15			15.
DSDP 94-12	12-1a	80.7	2.4-2.9			~3.
DSDP 94-13	12-1b	72.0	0.6(?)			0.6(?)
DSDP 149	12-4c	65.7		(0.8)		?
DSDP 149-2	12-2b	75.2		0.45		~0.5(?)
DSDP 149-3	12-2a	65.2	4.9			4.9*
DSDP 149-4	12-3a	68.3	~4(?)	2.2		~4.

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Table 3. Solution measurements (continued)

Amount of Solution (μm)						
Sample ¹	Number ²	%SiO ₂ ³	Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	Preferred Value ⁶
DSDP 149-5	12-3b	64.9-66.0	4.4			~4.
DSDP 149-6	12-3c	71.7-73.1	2.3			~2.
DSDP 149-7	12-3d	63.2	1.8			1.8
DSDP 149-8	12-4a	63.9	4.9			4.9
DSDP 149-10	12-5d	65.3-79.8	0.8-1			~1.
DSDP 149-11	12-5a	69.2	~1			~1.
DSDP 149-12	12-5b	64.0-65.6	~0.8	(1.7)		~0.8
DSDP 149-13	12-5c	61.6	9.1			~9.
DSDP 149-14	12-5e	65.4-65.9	2.2			~2.
DSDP 149-15	12-5f	68.7-69.2	0.7-1.4			~1.4
DSDP 166-1	12-6a	61.3		0.2		0.2
DSDP 167-1	12-7a	60.5-78.2		~1.0		~1.0 (?)
DSDP 216	13-5b	67.5		(4.8)		<5. (?)
DSDP 216-1	13-4	62.1			~10	~10. (?)
DSDP 216-2	13-5d	62.8-79.5		0.4		0.4
DSDP 216-3	13-5a	63.3	4.1-4.7		~5.5	~5.
DSDP 216-4	13-5c	64.4			~5.4	?
DSDP 216-6	13-6c	65.3		(1.3)	~11	~11. (?)
DSDP 216-7	13-6d	64.0			5.4-12	?
DSDP 292-1	13-2c	67.0	18.5			~18. (?)
DSDP 292-2	13-2b	68.3	26.3			26. (?)
DSDP 292-3	13-2e	72.3-76.6	6			~6.0
DSDP 292-4	13-2a	74.2			17-19	?
DSDP 292-5	13-2d	72.3		17		17.0
Micro-irghizites						
126-1		74.7		6.7-12		~10.
126-2		65.4		22.9		~23.
126-3		68.5			11-17	~17.

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Table 3. Solution measurements (continued)

Sample ¹	Number ²	%SiO ₂ ³	Amount of Solution (μm)			
			Silica-rich Protrusions ⁴	Cracks ⁵	U-shaped grooves	Preferred Value ⁶
126-4		69.7		7.4(?)		7.4(?)
126-5		62.5	14	14-26		14.
126-6		72.1		2.6		2.6(?)
127-7		71.5		(6)	~6	~6.
128-8		62.8		10-13		~12.
129-9		70.0		~15		~15.
128-10		64.4	~18	20		~20.0*
129-11		62.5	~28	~28	33	28.0*
128-12		64.8		6(?)		?
130-13		63.4	7-9			29. (?)
130-14		62.5	~9			29. (?)
130-15		62.7	14			14. (?)
128-16		63.5		~5		?
127-20		67.9		3.5(?)		?
166-4A		63.8		(1.2)(?)		?
166-5B		72.3		(10.8)(?)		?
Barbados Microtektites						
179-16-1		78.8		11.8-18.5		~11.
179-16-2		84.2		9.8-11.4		~10.
16-3		-	9-16			~12.
180-16-4		-	8.5			8.
179-16-5		76.0	11.5			~11.
179-16-6		73.2	9.5	4.9-8.2		~9. *
179-16-7		79.5	8.9-10.0	8.9-9.1		~10. *
179-16-9		77.2	18.5-24	10.8-24		~24. *
180-16-10		77.4	8.1-16.3	6		~16.
179-16-11		77.4		7-8		8. *
180-16-12		80.8	6.9			~7.
180-16-13		79.1	11-19.4			~18.
179-16-14		79.4		8.2-9.7		~9. *
180-16-16		78.3		13.5		~13. *

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Table 3. Solution measurements (continued)

¹Core and sample number for Australasian, Ivory Coast, and North American microtektites.
Sample number only for micro-irghizites and Barbados microtektites.

²SEM photomicrograph reference number.

³Weight percent SiO₂ determined by EDAX analysis (see table 6).

⁴Underlined values are for protrusions whose high SiO₂ contents were confirmed by EDAX.

⁵Values in parentheses indicate that the measurements were made on polished sections.
The apparent widths of the cracks are dependent on the angle between the crack and the polished surface. Thus the values may be too large in some cases.

⁶Values with asterisk are believed to be the best. The values with question marks after them are questionable.

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Table 4. Major Oxide Contents of Microtektites Used in This Study

Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
Australasian								
E 45-74 (1-4b)	56.67	25.18	4.30	4.48	6.48	0.55	0.76	1.16
E 45-89-1 (8-1a)	68.96	14.85	4.75	2.42	3.03	2.91	1.88	0.81
E 45-89-2 (8-1b)	53.56	13.58	6.70	18.67	4.51	1.80	0.08	0.72
E 49-4-1 (1-6d)	53.52	24.48	3.40	9.16	7.02	0.68	0.09	1.20
E 49-4-2 (1-6b)	64.82	18.85	6.12	3.09	4.20	0.61	1.04	0.84
E 49-4-3 (1-6c)	69.43	16.45	3.67	2.62	5.04	0.36	1.18	0.84
E 49-4-4 (1-7)	72.26	14.15	5.07	1.53	3.59	0.67	1.20	1.10
E 49-4-5 (1-8)	69.64	15.63	5.16	2.91	3.92	0.43	1.11	0.84
E 49-51-2 (2-1a)	44.83	35.48	4.79	3.07	9.98	0.22	0.29	0.97
LSDH-23G-1 (4-7a)	58.73	20.68	5.69	7.62	4.95	0.51	0.22	1.20
LSDH-23G-2 (4-7b)	61.73	19.88	4.76	6.48	4.24	0.94	0.38	1.14
MSN-48G-1 (4-8b)	61.09	17.77	3.51	9.35	5.46	0.97	0.22	1.23
MSN-48G-2 (4-8c)	69.79	13.86	5.35	3.20	3.36	1.17	2.12	0.70
RC9-142-1 (2-3)	61.20	13.97	7.98	9.85	4.80	0.67	0.32	0.80
RC9-142-2 (2-4a)	62.32	11.93	6.87	9.12	7.30	0.66	0.69	0.65
RC9-142-3 (2-4b)	58.20	15.63	5.60	12.63	5.60	0.85	0.08	1.00
RC9-143-1 (2-5b)	71.99	11.15	5.53	5.07	2.62	0.97	1.77	0.52
RC9-143-3 (2-5c)	73.94	10.23	4.74	5.25	3.16	0.46	1.17	0.60
RC12-327 (2-6)	63.32	20.33	3.50	4.59	5.85	0.24	0.50	1.27
RC12-328 (2-7)	56.25	20.18	4.79	10.23	6.26	0.70	0.06	1.12
V16-70-1 (2-8a)	59.21	20.71	5.17	7.36	5.03	0.52	0.37	1.25
V16-70-2 (2-8b)	65.78	17.92	4.41	4.57	4.44	0.36	0.77	1.39
V16-70-3 (2-8c)	63.52	16.57	5.98	6.70	4.78	0.48	0.54	1.00

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Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
V16-76-1 (3-1a)	70.20	15.47	4.22	3.51	3.60	0.45	1.21	0.94
V16-76-2 (3-1b)	56.45	23.02	3.62	8.65	5.74	0.61	0.16	1.32
V19-153-1 (3-2d)	54.39	15.23	5.01	18.81	4.33	1.02	0.06	0.78
V19-153 BGR-1(3-3b)	54.19	15.47	7.32	16.58	3.94	1.05	0.12	0.90
V19-169-1 (3-4a)	65.46	16.24	6.23	2.86	3.71	1.22	2.86	1.06
V19-169-3 (3-4c)	71.04	13.80	5.23	3.83	3.69	0.25	0.99	0.74
V20-138 (3-6d)	64.56	14.90	5.99	7.02	4.79	0.99	0.38	0.94
V20-138-1 (3-6f)	63.10	19.26	4.81	3.72	5.49	0.96	0.98	1.23
V20-138-3 (3-6c)	76.19	10.10	4.51	3.38	2.30	1.05	1.50	0.60
V20-138-4 (3-6e)	63.21	13.56	10.18	5.29	3.79	1.05	1.68	0.86
V20-138-6 (3-7d)	66.67	13.65	6.74	4.74	3.39	1.45	2.15	0.84
V20-138-7 (3-7a)	64.44	16.21	5.77	4.90	4.16	1.22	2.09	0.81
V20-138-8 (3-7b)	67.17	12.12	8.03	4.46	3.30	1.25	2.39	0.86
V20-138-9 (3-7c)	68.30	14.97	3.49	6.37	3.51	0.72	1.23	0.96
V20-138-10 (3-8a)	65.95	13.05	6.37	8.11	3.65	1.10	0.50	0.86
V20-138-11 (3-8b)	68.90	13.56	5.70	2.68	3.74	1.33	2.87	0.76
V20-184 (4-1)	56.54	24.32	3.68	5.92	7.33	0.41	0.22	1.15
V28-238 (4-2)	65.83	16.70	4.95	2.83	3.98	1.60	2.76	0.94
V28-239-2 (4-3c)	55.25	27.12	4.34	4.40	5.19	0.85	0.76	1.70
V28-239-3 (4-3a)	56.93	26.05	4.56	4.45	4.42	0.72	0.97	1.46
V28-239-4 (4-3b)	56.80	24.96	5.65	4.17	4.94	0.78	0.84	1.48
V28-239-5 (4-3d)	55.57	25.85	4.41	4.44	6.55	0.60	0.78	1.35
V29-40 (4-6)	64.33	17.62	4.82	5.72	4.97	0.62	0.40	1.17

Ivory Coast

K9-56-1 (5-1a)	67.85	16.89	6.06	3.30	1.18	2.01	1.79	0.55
K9-56-2 (5-1d)	65.71	17.10	6.51	4.43	1.52	2.16	1.57	0.58

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Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
K9-56-3	(5-1b)	63.93	17.50	7.14	4.79	1.74	1.55	0.62
K9-56-5	(6-1c)	67.84	15.50	6.61	4.01	1.13	1.70	0.69
K9-56-6	(6-1a)	65.00	17.52	6.65	6.01	1.63	0.86	0.54
K9-56-7	(6-1b)	67.97	16.25	6.00	4.00	1.38	1.45	0.61
K9-56-10	(6-5a)	68.52	15.73	5.97	3.41	1.61	1.64	0.45
K9-56-11	(8-2b)	67.86	16.58	6.34	3.82	1.76	1.14	0.58
K9-56-12	(8-2a)	67.61	16.47	5.97	3.95	1.65	1.31	0.54
K9-56-13	(8-3)	69.43	15.28	6.08	3.18	1.34	1.69	0.54
K9-56-14	(8-4)	67.97	16.45	6.18	3.44	1.68	1.56	0.53
K9-56-15	(8-5)	68.53	16.34	5.91	3.55	1.71	1.00	0.61
K9-56-16	(8-6a)	66.94	16.17	6.44	3.93	1.61	1.66	0.48
K9-56-26	(10-8a)	66.98	15.43	7.01	4.50	1.54	1.51	0.52
K9-56-27	(10-8c)	67.28	15.60	5.75	4.31	1.57	1.87	0.43
K9-57-2	(5-2c)	64.98	16.89	6.97	5.52	1.34	1.29	0.58
K9-57-4	(5-2d)	67.16	16.27	6.50	3.99	1.10	1.92	0.61
K9-57-6	(5-3a)	66.77	14.93	7.26	4.87	1.59	1.59	0.58
K9-57-7	(5-3b)	64.38	15.22	8.41	5.89	1.32	1.70	0.49
K9-57-8	(10-7f)	64.96	15.49	7.12	5.80	1.42	1.71	0.53
V19-297-1	(5-5b)	67.45	16.06	6.34	4.33	1.46	1.61	0.52
V19-297-3	(5-6c)	69.02	9.83	7.67	5.48	1.50	2.89	0.27
V19-297-4	(5-7a)	67.03	16.04	6.39	3.91	1.89	1.88	0.39
V19-297-5	(5-7b)	66.27	16.57	6.87	4.02	1.49	1.70	0.61
V19-297-6	(5-8a)	66.43	16.70	6.27	3.44	1.69	1.95	0.49
V19-297-7	(10-7c)	66.36	16.64	6.53	4.46	1.70	1.36	0.58
V19-300-1	(10-7d)	64.41	16.49	6.71	5.41	1.33	2.09	0.56
V19-300-2	(10-7e)	66.11	16.06	6.59	4.88	1.48	1.61	0.45
V27-239-1	(5-4d)	69.54	15.63	5.97	2.87	1.14	1.83	0.59

Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
V27-239-2 (5-4b)	62.14	16.48	7.23	6.62	1.62	2.82	2.05	0.62
V27-239-3 (5-4c)	65.17	16.44	6.62	5.04	1.73	2.39	1.51	0.64
V27-239-4 (5-4a)	70.04	15.37	5.95	2.74	1.20	1.90	1.82	0.56
V27-239-5 (5-4e)	68.28	16.47	5.93	2.94	0.97	2.42	2.03	0.57
V27-239-6 (6-6b)	65.56	15.63	6.86	5.05	1.16	2.77	2.04	0.54
V27-239-7 (6-6a)	65.14	16.27	7.33	4.76	1.56	2.14	1.62	0.75
V27-239-8 (6-7)	68.04	17.23	5.56	3.29	1.24	2.03	1.47	0.71

North American

RC9-58 (10-1b)	66.96	16.44	5.62	2.08	1.51	1.74	4.11	1.15
RC9-58-1 (7-1)	70.11	16.96	5.06	1.66	1.03	0.98	2.85	0.98
RC9-58-2 (7-2a)	75.03	13.65	3.66	1.38	1.12	0.96	3.16	0.68
RC9-58-3 (7-2c)	72.37	12.93	4.26	1.84	1.91	1.43	3.73	1.13
RC9-58-7 (7-5a)	75.24	12.83	3.56	1.16	1.83	1.19	2.95	0.80
RC9-58-8 (7-5b)	64.17	16.90	6.64	3.17	3.23	1.26	3.20	1.03
RC9-58-9 (7-6a)	65.08	17.47	6.38	2.18	1.74	1.59	3.80	1.34
RC9-58-10 (7-6c)	66.97	15.16	6.66	2.40	2.51	1.44	3.37	1.09
RC9-58-11 (7-7b)	64.58	17.20	6.18	2.99	2.97	1.17	3.33	1.18
RC9-58-14 (8-8b)	85.61	7.90	1.91	0.66	0.55	0.69	2.00	0.28
RC9-58-14 (8-8b)	77.79	12.35	3.03	1.00	0.81	1.21	2.90	0.49
RC9-58-15 (8-6b)	79.32	10.70	3.03	1.05	1.07	1.02	2.87	0.58
RC9-58-16 (8-7a)	64.85	17.29	6.08	2.66	2.46	1.71	3.37	1.15
RC9-58-17 (8-7c)	77.44	11.78	2.64	1.09	1.22	1.41	3.58	0.47
RC9-58-18 (9-1a)	75.19	12.73	3.05	1.30	1.52	1.28	4.07	0.46
RC9-58-19 (9-1c)	78.90	11.40	3.00	0.93	0.54	1.10	2.91	0.87

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Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
RC9-58-20	(9-3b)	67.52	16.06	5.51	1.69	1.43	1.45	1.07
RC9-58-21	(9-4a)	79.63	11.31	2.59	1.00	0.52	1.02	0.53
RC9-58-22	(9-6a)	64.07	17.29	6.17	3.56	3.87	1.17	0.89
RC9-58-23	(9-7c)	73.92	14.17	3.93	1.24	1.41	1.25	0.84
RC9-58-23	(9-7c)	66.97	17.53	5.89	2.29	2.21	1.14	0.83
RC9-58-23	(9-7c)	68.03	17.34	5.32	2.23	2.13	1.04	0.83
RC9-58-23	(9-7c)	64.17	18.23	6.65	2.72	2.25	1.59	1.12
RC9-58-24	(9-7a)	80.21	11.31	2.01	0.76	0.54	1.28	0.44
RC9-58-25	(9-8a)	77.12	13.25	3.07	1.03	0.87	0.86	0.68
RC9-58-26	(10-1a)	65.45	16.79	6.03	3.18	2.29	1.35	1.16
RC9-58-27	(10-1c)	64.53	16.60	6.39	3.52	3.21	1.30	0.92
RC9-58-28	(10-2a)	76.12	13.37	3.62	1.00	0.97	0.92	0.66
RC9-58-29	(10-3a)	77.15	12.45	3.20	1.24	0.66	1.20	0.54
RC9-58-30	(10-4a)	61.36	17.50	6.47	4.11	4.46	1.47	1.22
RC9-58-30	(10-4a)	62.54	17.77	5.70	4.25	3.51	1.71	1.03
RC9-58-31	(10-4b)	74.93	13.84	3.30	0.97	0.63	1.30	0.76
RC9-58-31	(10-4b)	70.78	15.01	5.41	1.48	1.42	1.19	0.83
RC9-58-34	(11-1a)	74.83	13.92	3.00	0.96	0.73	1.71	0.71
RC9-58-36	(11-2c)	73.45	14.54	2.73	1.03	1.07	1.73	0.80
RC9-58-37	(11-2b)	65.74	14.90	6.67	3.50	3.88	1.49	0.84
RC9-58-38	(11-2a)	66.75	15.22	5.99	2.91	2.96	1.59	0.87
RC9-58-38	(11-2a)	66.37	15.42	6.75	2.72	2.61	1.52	0.73
RC9-58-39	(11-3a)	64.15	17.24	5.94	3.20	3.36	1.47	1.04
RC9-58-40	(11-4a)	80.64	11.28	2.20	0.75	0.27	1.25	0.34
RC9-58-41	(11-4b)	63.94	16.63	6.40	3.20	4.38	1.48	1.19

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Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
DSDP 70A (13-1)	60.97	20.46	5.22	8.45	1.66	1.04	0.24	1.56
DSDP 94 (11-8b)	95.88	2.08	0.17	0.35	0.04	0.53	0.50	0.06
DSDP 94 (11-8b)	74.61	13.82	3.45	1.61	1.59	1.30	2.47	0.77
DSDP 94 (11-8b)	73.12	14.52	3.79	1.77	1.65	1.53	2.47	0.75
DSDP 94-1 (11-5a)	70.89	13.88	3.98	1.64	2.28	2.54	3.63	0.74
DSDP 94-2 (11-5b)	74.14	11.93	3.43	0.75	0.96	2.08	5.60	0.66
DSDP 94-3 (11-5c)	81.38	10.57	2.37	0.55	0.75	1.24	2.38	0.35
DSDP 94-4 (11-6a)	75.40	13.27	4.29	0.93	0.98	1.38	2.83	0.48
DSDP 94-5 (11-6b)	77.66	12.10	3.34	0.82	1.08	1.25	2.83	0.54
DSDP 94-6 (11-6c)	78.70	12.11	3.01	0.68	0.59	1.30	2.70	0.51
DSDP 94-6 (11-6c)	77.75	12.74	2.97	0.77	0.86	1.32	2.72	0.50
DSDP 94-7 (11-7e)	79.27	11.51	2.78	0.78	0.84	1.11	2.80	0.46
DSDP 94-8 (11-7a)	75.84	13.05	2.04	0.67	0.91	2.13	4.66	0.30
DSDP 94-9 (11-7b)	77.19	11.04	3.22	0.66	0.83	2.20	3.78	0.70
DSDP 94-10 (11-7c)	77.32	12.94	1.91	0.57	1.06	1.86	3.57	0.39
DSDP 94-11 (11-7d)	81.74	10.10	1.90	0.56	0.37	1.73	2.81	0.42
DSDP 94-12 (12-1a)	80.69	11.90	1.42	0.84	0.21	1.17	2.74	0.63
DSDP 94-13 (12-1b)	71.99	13.29	4.17	1.38	2.26	2.06	3.87	0.63
DSDP 94-13 (12-1b)	73.15	13.71	3.27	1.39	2.35	1.25	3.88	0.58
DSDP 149 (12-4c)	65.74	17.53	6.32	2.62	1.88	1.32	3.16	1.04
DSDP 149-2 (12-2b)	75.22	13.22	2.97	0.78	0.54	1.36	4.80	0.75
DSDP 149-3 (12-2a)	65.17	16.86	6.14	3.17	2.40	1.63	3.19	1.06
DSDP 149-4 (12-3a)	68.34	15.39	5.38	2.92	2.79	1.07	2.80	0.88
DSDP 149-4 (12-3a)	64.93	17.24	5.69	3.42	3.56	1.15	2.63	0.97
DSDP 149-5 (12-3b)	65.98	16.64	5.78	2.65	2.38	1.39	3.81	1.01
DSDP 149-5 (12-3b)	64.92	17.24	5.71	2.84	2.51	1.45	3.69	1.20

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Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
DSDP 149-6 (12-3c)	71.73	15.23	4.77	1.30	1.23	1.11	3.35	0.90
DSDP 149-6 (12-3c)	73.11	14.36	4.26	1.30	1.17	1.24	3.21	0.90
DSDP 149-7 (12-3d)	63.25	16.68	5.73	3.77	4.67	1.34	3.09	1.05
DSDP 149-8 (12-4a)	63.86	18.11	6.33	3.54	2.65	1.34	2.61	1.13
DSDP 149-10 (12-5d)	65.34	18.13	6.32	2.04	1.82	1.17	3.58	1.16
DSDP 149-10 (12-5d)	79.79	11.30	2.01	0.71	0.60	1.06	3.71	0.43
DSDP 149-11 (12-5a)	69.16	16.31	5.62	2.04	1.61	1.07	2.67	1.15
DSDP 149-12 (12-5b)	65.60	16.94	6.21	2.81	2.54	1.40	3.11	1.02
DSDP 149-12 (12-5b)	63.97	18.67	5.64	2.97	2.36	1.60	3.22	1.21
DSDP 149-13 (12-5c)	61.59	18.62	7.17	3.98	3.10	1.21	2.83	1.07
DSDP 149-14 (12-5e)	65.43	16.80	5.90	2.60	2.66	1.58	3.44	1.17
DSDP 149-14 (12-5e)	65.91	17.99	5.69	1.94	1.39	1.54	3.92	1.26
DSDP 149-15 (12-5f)	69.22	16.52	5.01	1.66	1.56	1.24	3.30	1.10
DSDP 149-15 (12-5f)	68.73	16.06	5.10	2.08	2.25	1.26	2.98	1.12
DSDP 166-1 (12-6a)	61.29	6.80	6.83	9.40	11.94	1.61	1.47	0.23
DSDP 166-2 (12-6b)	59.02	8.80	9.75	6.32	10.68	2.17	2.55	0.34
DSDP 167-1 (12-7a)	60.53	8.58	7.79	5.04	2.59	6.02	8.64	0.42
DSDP 167-1 (12-7a)	78.23	10.29	2.24	0.79	0.60	1.24	5.69	0.53
DSDP 216 (13-5b)	67.49	7.90	3.67	6.09	11.07	1.13	1.85	0.36
DSDP 216-1 (13-4)	62.13	13.03	6.66	6.14	6.73	2.07	2.11	0.73
DSDP 216-2 (13-5d)	79.53	9.90	1.93	1.24	2.16	1.60	3.10	0.13
DSDP 216-2 (13-5d)	66.92	7.40	5.48	5.67	10.40	1.07	2.43	0.25
DSDP 216-2 (13-5d)	62.85	7.06	5.64	9.34	11.05	1.10	2.16	0.40
DSDP 216-3 (13-5a)	63.27	13.57	7.03	5.47	5.42	1.96	2.21	0.65
DSDP 216-4 (13-5c)	64.45	14.37	5.73	4.10	5.24	2.07	2.86	0.76
DSDP 216-6 (13-6c)	65.31	10.17	5.71	4.99	5.95	2.83	4.22	0.37
DSDP 216-7 (13-6d)	63.95	9.84	8.21	3.14	4.80	1.96	2.37	0.32

Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
DSDP 216-7 (13-6d)	72.09	12.12	6.12	0.69	3.45	1.48	3.14	0.46
DSDP 292-1 (13-2c)	67.02	14.18	4.74	2.25	3.08	4.60	2.83	0.94
DSDP 292-2 (13-2b)	68.30	15.11	5.51	2.18	3.32	1.33	2.90	0.88
DSDP 292-3 (13-2e)	72.32	13.26	4.62	2.03	1.61	1.91	2.98	0.81
DSDP 292-3 (13-2e)	76.65	11.24	3.55	1.57	1.61	1.35	2.87	0.80
DSDP 292-4 (13-2a)	74.17	12.49	3.82	3.18	2.32	0.86	1.95	0.85
DSDP 292-5 (13-2d)	72.34	12.43	4.72	2.75	3.82	0.94	1.93	0.64
Micro-irghizites								
126-1	74.7	11.9	3.88	1.29	2.84	1.84	2.39	0.56
126-2	65.4	16.6	7.18	3.44	2.92	1.61	1.81	0.75
126-3	68.5	13.1	5.34	2.21	4.50	1.69	1.93	0.62
126-4	69.7	11.8	5.52	2.23	4.20	1.62	2.16	0.53
126-5	62.5	13.0	10.3	5.44	3.01	1.57	1.62	0.59
126-6	72.1	12.4	5.03	2.11	6.79	1.22	1.62	0.58
127-7	71.5	15.0	5.37	2.57	1.05	1.95	1.91	0.83
128-8	62.8	14.0	8.6	4.2	3.9	1.6	1.9	0.64
129-9	70.0	15.0	5.65	2.50	0.99	1.89	2.03	0.84
128-10	64.4	17.2	6.7	3.0	2.6	1.3	1.7	0.63
129-11	62.5	12.7	10.9	6.38	2.79	1.82	1.59	0.62
128-12	64.8	12.6	8.8	4.2	3.9	1.4	1.6	0.57
130-13	63.4	11.7	10.7	5.5	3.5	1.4	1.4	0.63
130-14	62.5	10.6	11.4	6.2	3.5	1.6	1.4	0.54
130-15	62.7	10.5	11.9	6.6	1.9	2.3	1.6	0.61
128-16	63.5	12.6	11.2	6.71	1.96	1.64	1.65	0.68
127-20	67.9	15.6	8.12	3.96	1.74	2.18	1.98	0.81

Sample No.	SiO ₂	Al ₂ O ₃	FeO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
166-4A	63.8	13.9	8.2	3.6	3.8	1.2	1.9	0.69
166-5B	72.3	11.4	4.2	1.4	5.4	1.0	1.8	0.50
Barbados Microtektites								
179-16-1	78.8	12.4	3.05	0.71	0.23	1.32	2.55	0.58
179-16-2	84.2	10.4	1.48	0.48	0.20	0.60	1.77	0.49
179-16-5	76.0	13.5	3.68	0.96	0.78	1.23	2.78	0.64
179-16-6	73.2	12.6	4.65	1.35	4.46	0.92	1.84	0.56
179-16-7	79.5	12.5	2.35	0.74	0.19	1.17	2.49	0.62
179-16-9	77.2	12.8	3.20	1.03	0.70	1.32	2.65	0.64
180-16-10	77.4	12.9	3.02	0.80	0.75	1.23	2.73	0.69
179-16-11	77.4	12.8	3.92	0.87	0.29	1.35	2.47	0.51
180-16-12	80.8	11.1	2.14	0.63	0.63	1.11	2.90	0.26
180-16-13	79.1	12.1	2.42	0.92	0.74	1.24	2.71	0.43
179-16-14	79.4	11.7	3.23	0.61	0.35	1.28	2.54	0.54
180-16-16	78.3	12.7	3.15	0.94	0.39	1.12	2.32	0.64

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Table 5. Composition of microtektites with similar SiO_2 contents but different amounts of solution from various sites

	Australasian Sites						
	RC9-142		V20-138			V20-138	
	1	2	6	10	8	9	11
SiO_2	61.2	62.3	66.7	65.9	67.2	68.3	68.9
Al_2O_3	14.0	11.9	13.6	13.0	12.7	15.0	13.6
FeO	8.0	6.9	6.7	6.4	8.0	3.5	5.7
MgO	9.8	9.1	4.7	8.1	4.5	6.4	2.7
CaO	4.8	7.3	3.4	3.6	3.3	3.5	3.7
Na_2O	0.7	0.7	1.4	1.1	1.2	0.7	1.3
K_2O	0.3	0.7	2.2	0.5	2.4	1.2	2.9
TiO_2	0.80	0.65	0.84	0.86	0.86	0.96	0.76
Amt. Solution (μm)	4.3	12	1.8	4	4.8(?)	0.6(?)	2.6

	Australasian V28-239			Ivory Coast V19-297		
	4	5	2	7	6	5
SiO_2	56.8	55.6	55.2	66.4	66.4	66.3
Al_2O_3	25.0	25.9	27.1	16.6	16.7	16.6
FeO	5.6	4.4	4.3	6.5	6.3	6.9
MgO	4.2	4.4	4.4	4.5	3.4	4.0
CaO	4.9	6.6	5.2	1.7	1.7	1.5
Na_2O	0.8	0.6	0.8	2.0	2.6	2.0
K_2O	0.8	0.8	0.8	1.4	1.9	1.7
TiO_2	0.84	1.4	1.7	0.58	0.49	0.61
Amt. Solution (μm)	6.5	11.8(?)	16	7.6	~13	25

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Table 5 (Cont.)

	Ivory Coast V27-239			North American RC9-58		
	7	3	6	37	26	16
SiO ₂	65.1	65.2	65.6	65.7	25.4	64.8
Al ₂ O ₃	16.3	16.4	15.6	14.9	16.8	17.3
FeO	7.3	6.6	6.9	6.7	6.0	6.1
MgO	4.8	5.0	5.0	3.5	3.2	2.7
CaO	1.6	1.7	1.2	3.9	2.3	2.5
Na ₂ O	2.1	2.4	2.8	1.5	1.4	1.7
K ₂ O	1.6	1.5	2.0	2.6	3.3	3.4
TiO ₂	0.75	0.64	0.54	0.84	1.2	1.2
Amt. Solution (μm)	0.8	1.6	2	4.6	~10	~28

	North American RC9-58					Micro-Irghizites		
	27	8	41	39	22	8	5	11
SiO ₂	64.5	64.2	63.9	64.2	64.1	62.8	62.5	62.9
Al ₂ O ₃	16.6	16.9	16.6	17.2	17.3	14.0	11.0	10.9
FeO	6.4	6.6	6.4	5.9	6.2	8.6	10.5	11.7
MgO	3.5	3.2	3.2	3.2	3.6	4.2	5.7	6.9
CaO	3.2	3.2	4.4	3.4	3.9	3.9	2.8	2.9
Na ₂ O	1.3	1.3	1.5	1.5	1.2	1.6	1.3	1.4
K ₂ O	3.1	3.2	2.4	3.2	2.6	1.9	1.4	1.4
TiO ₂	0.92	1.0	1.2	1.0	0.89	0.64	0.60	0.64
	~0.5	1.4	3.2	6.7	~10	12	14	28

Table 5 (cont.)

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Barbados Microtektites						
	14	1	3	11	10	9
SiO ₂	79.4	78.8	79.1	77.4	77.4	77.2
Al ₂ O ₃	11.7	12.4	12.1	12.8	12.9	12.8
FeO	3.2	3.0	2.4	3.9	3.0	3.2
MgO	0.61	0.71	0.92	0.87	0.80	1.0
CaO	0.35	0.23	0.74	0.29	0.75	0.70
Na ₂ O	1.3	1.3	1.2	1.4	1.2	1.3
K ₂ O	2.5	2.6	2.7	2.5	2.7	2.6
TiO ₂	0.54	0.58	0.43	0.51	0.69	0.65
Amt. Solution (μm)	9	~11	~18	8	~16	~24

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Table 6. Estimated average amounts of solution, depths, sediment accumulation rates, mixing coefficients, and sediment types for selected cores.

	Ave. Solution (μm) *	Depth (m)	Sed. rate (cm/1000 yr.)	Mixing Coef. $\text{cm}^2/10^3 \text{ yr.}$	Sediment Type \pm
Australasian					
V16-70	0.5 (3)	4649	0.22	0.2	foram. lutite
V20-138	1.5 (9)	4141	0.46	--	lutite
E49-4	4.5 (2)	3568	0.21 (?)	--	foram. lutite
Ivory Coast					
V27-239	1 (7)	4346	1.02	--	foram. ooze
K9-57	~1 (3)	4479	1.59	--	foram. lutite
V19-300	1 (2)	4152	0.84	--	foram. lutite
V19-297	~5 (4)	4020	0.71	40	foram. lutite
K9-56	16 (7)	4687	1.68	--	foram. lutite
North American					
DSDP 149	~2 (11)	3972	0.27	--	rad. ooze
DSDP 216	~5 (4)	2262	0.25	--	nanno. chalk
RC9-58	3 (23)	3456	(1?)	?	foram. lutite
DSDP 94	13 (6)	1793	1.2	--	nanno. chalk
DSDP 292	17 (3)	2943	1.1	--	nanno. chalk

* Estimated average amount of solution at ~70% SiO_2 .
Number in parentheses is number of measurements.

** Data from Officer and Lynch (1982)

\pm foram. = foraminiferal, rad. = radiolarian, nanno. = nannofossil

Table 7. Average values for solution and SiO₂ content.

	Solution (μm) ¹ Range	Mean	Average SiO ₂ Content (Wt.%) ¹
Australasian Microtektites			
Reliable data only ²	1.8 - 16	7.2 ± 4.3(17)	64.0 ± 5.9(14)
Reliable + fairly reliable	1.8 - 16	7.5 ± 4.0(26)	63.4 ± 5.8(23)
All data ³	0.4 - 16	5.4 ± 4.4(50)	63.7 ± 6.1(42)
Ivory Coast Microtektites			
Reliable data only ²	0.9 - 18	9.7 ± 7.3(9)	67.3 ± 2.0(9)
Reliable + fairly reliable	0.8 - 25	8.3 ± 7.2(20)	66.6 ± 2.0(29)
All data ³	0.8 - 25	9.8 ± 7.3(25)	66.5 ± 1.9(24)
North American Microtektites			
Reliable data only ²	3.2 - 4.9	4.2 ± 0.9(3)	64.9 ± 0.9(3)
Reliable + fairly reliable	0.2 - 28	5.2 ± 5.7(41)	70.1 ± 7.2(32)
All data ³	0.2 - 28	5.3 ± 6.8(63)	71.3 ± 6.7(54)
Micro-Irghizites			
Reliable data only ²	14 - 28	20.7 ± 7.0(3)	63.3 ± 1.0(3)
Reliable + fairly reliable	6 - 28	15.6 ± 6.9(9)	66.8 ± 4.4(9)
All data ³	2.6 - 28	13.7 ± 7.2(12)	67.1 ± 4.2(12)
Barbados Microtektites			
Reliable data only ²	8 - 24	12.2 ± 6.0(6)	77.5 ± 2.3(6)
Reliable + fairly reliable	7 - 24	11.9 ± 4.6(14)	78.4 ± 2.7(12)
All data ³	7 - 24	11.9 ± 4.6(14)	78.4 ± 2.7(12)

- 1) ± one standard deviation. The number in parentheses indicates the number of measurements.
- 2) Usually indicates solution values where two or more measurements agree or where two different criteria agree. Indicated by * in table 3.
- 3) Includes some fairly questionable measurements indicated by (?) in table 3.

Figure 1. Scanning electron microscope (SEM) photomicrographs of microtektites with cracks. A. Micro-irghizite (126-5) with cracks ranging from 28 to 52 μm in width. B. Ivory Coast microtektite (K9-56-26) with a ≈ 31 μm wide crack. A silica-rich protrusion (not visible) is ≈ 16 μm high. C. North American microtektite from Barbados (179-16-11) with a 15 μm wide crack. D. North American microtektite from Barbados (180-16-16) with a 27 μm wide crack. Scale bars for A-C equal 100 μm , for D equals 40 μm .

Figure 2. SEM photomicrographs of microtektites with silica-rich protrusions. A. Australasian microtektite (V20-138-6) with silica-rich protrusions barely exposed. The silica-rich protrusions are elevated only 1.3 to 1.8 μm above the surrounding surface. B. Australasian microtektite (E49-4-1) with two well exposed silica-rich protrusions elevated 9.1 μm above the adjacent microtektite surface. C. Australasian microtektite (V16-70-1) with silica-rich protrusions elevated 11 μm above the adjacent surface. The smaller silica-rich particle is almost fully exposed. D. Ivory Coast microtektite (K9-56) with silica-rich protrusions elevated 20 μm above the adjacent surface. Note the pedestal of tektite glass under the silica-rich particle. The hemispherical shape of the silica-rich particle is seen in transmitted light with an optical microscope (see insert). The small conical protrusion at the edge near the top of the microtektite may indicate where a smaller silica-rich particle was completely removed by solution. Scale bar for A equals 20 μm , for B equals 50, for C equals 100, and for D and insert in D equals 25 μm .

Figure 3. SEM photomicrographs of microtektites with both cracks and silica-rich protrusions. A. Ivory Coast microtektite (K9-56-13). The silica-rich protrusions are elevated about 16-17 μm above the surrounding surface and the cracks are about 28 μm wide. Thus the width of the cracks are a little less than twice the height of the silica-rich protrusions. B. North American microtektite from Barbados (179-16-9). The silica-rich protrusions stand 8.9 to 10 μm above the surface and the crack is 17.8 to 18.2 μm wide. C. Micro-irghizite (128-10). The cracks are about 40 μm wide. D. Same micro-irghizite as in C. The silica-rich particle at the top is elevated about 18 μm above the surface. Scale bars for A-D equal 100 μm .

Figure 4. Sketch showing progressive solution of microtektite with silica-rich hemisphere at surface. A. Original occurrence of silica-rich inclusion. B. After enough solution to expose only a small part of the sides of the silica-rich particle. Compare with Fig. 2 A. C. Solution has exposed almost the entire silica-rich particle which now stands on a pedestal of tektite glass that was temporarily protected from solution by the overlying silica-rich particle. Compare with Fig. 2 B-C. D. Solution has freed the silica-rich particle. A conical-shaped protrusion of tektite glass marks the former location of the silica-rich particle.

Figure 5. SEM photomicrograph of Ivory Coast microtektite (K9-56-11) with U-shaped grooves. The grooves are about 80 μm wide. Scale bar equals 100 μm .

Figure 6. SEM photomicrographs of microtektites, in or removed from, agglutinated foraminifera tests. A. Agglutinated foraminifera test from RC9-58 with at least five microtektites visible including one fused pair. B. Agglutinated foraminifera test from DSDP site 166, core 12, section 6, 45-47 cm, with numerous microtektites visible. Some are clinopyroxene-bearing and etched crystals are clearly visible. C. Agglutinated foraminifera test from DSDP site 166, core 12, section 6, 45-47 cm, with numerous microtektites and sponge spicules visible. D. Close-up view of contact between the two large microtektites on lower right of test in C. The spherule on the right is a clinopyroxene-bearing microtektite. The two spherules are separated by less than 0.5 μm indicating less than 0.25 μm of combined solution. E. Agglutinated foraminifera test from RC9-58 with one large microtektite near the center. F. Enlargement of the microtektite in E. The protrusion has a relief of ~ 16 μm . G. Close-up view of a microtektite in a fragment of an agglutinated foraminifera test from DSDP 149, core 31, section 1, 5 cm. H and I. Views of the surface of the microtektite that was enclosed in the test in G. Note the silica-rich protrusion which has a relief of about 4.7 μm . There is no obvious difference in relief between the surface that was exposed and the one that was enclosed in the test. Scale bars for A-C and E equal 100 μm , for D equals 4 μm , for F, H, and I equal 20 μm , and for G equals 50 μm .

Figure 7. A-D. SEM photomicrographs of polished sections of Ivory Coast microtektites (core K9-56) with exposed bubble cavities. The microtektites are mounted in epoxy (dark grey). A, C, and D have bubble cavities (with

white borders) in the epoxy which were charging. Extrapolation of the bubble cavities and microtektite surfaces indicate a minimum of about 9, 5, <1.5, and <0.5 μm of solution in A, B, C, and D, respectively.

Figure 8. Amount of solution versus SiO_2 content of microtektites from one site from each of the strewn fields.

Figure 9. Amount of solution versus SiO_2 content for Australasian microtektites and micro-irghizites.

Figure 10. Amount of solution versus SiO_2 content for North American microtektites from deep-sea sites and from Barbados.

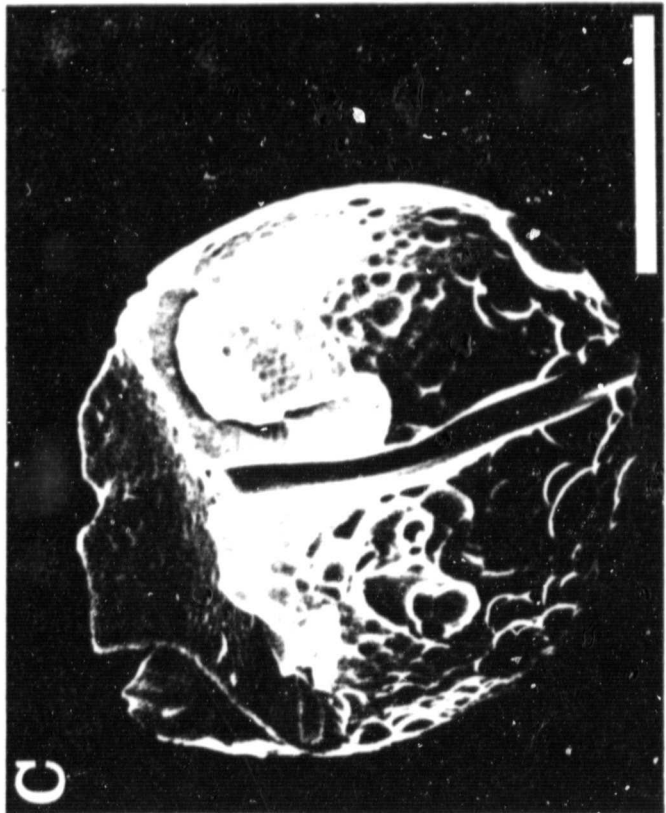
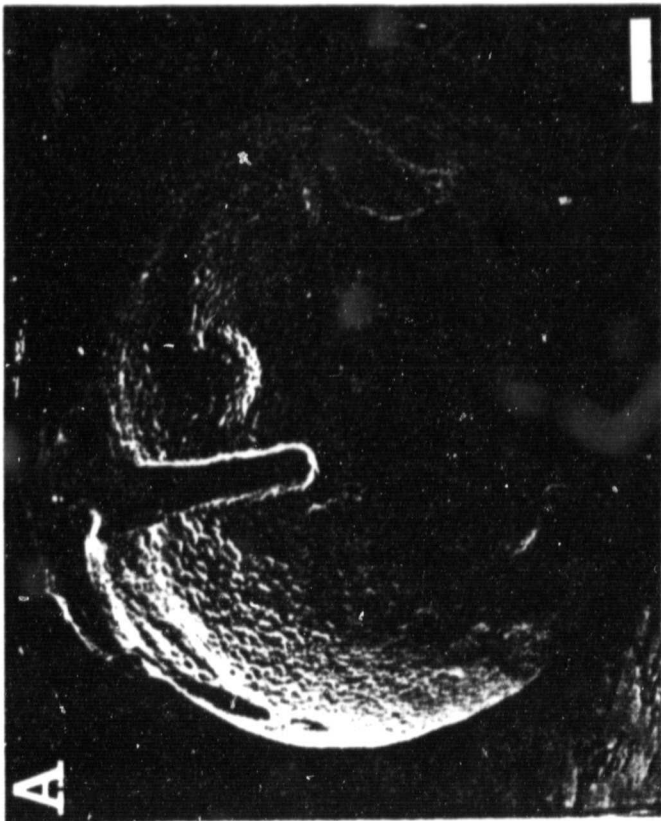
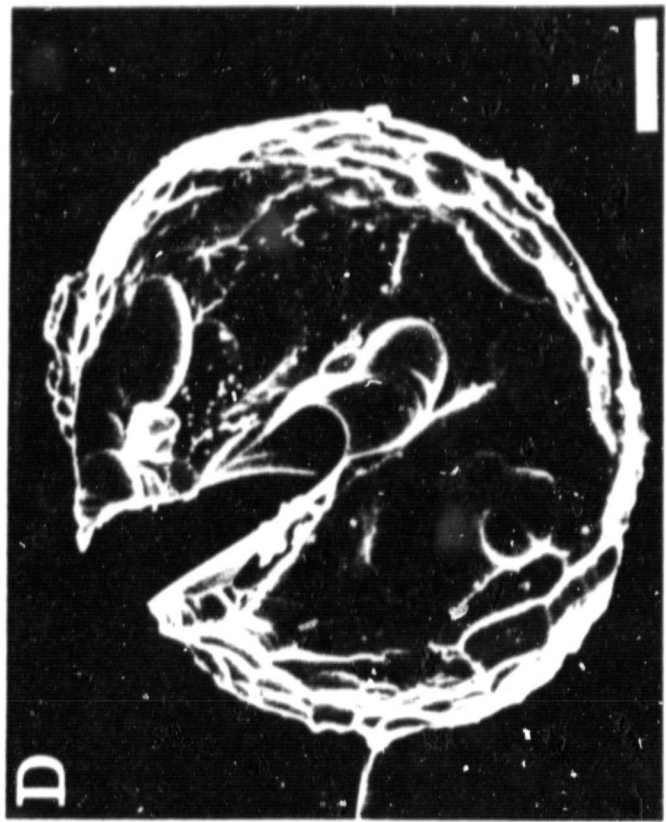
Figure 11. Amount of solution versus SiO_2 content of microtektites from different sites within the Australasian strewn field.

Figure 12. Amount of solution versus SiO_2 content of microtektites from different sites within the Ivory Coast strewn field.

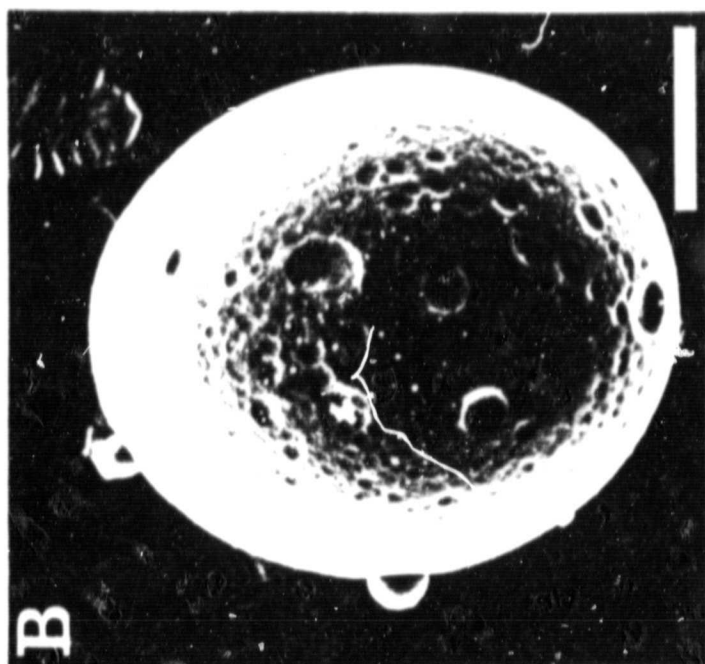
Figure 13. Amount of solution versus SiO_2 content for microtektites from various sites within the North American strewn field.

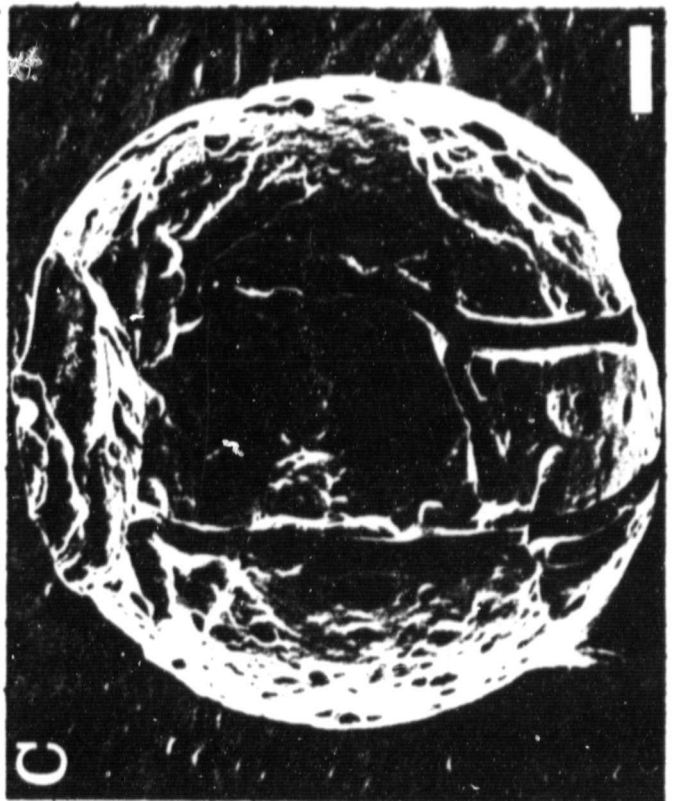
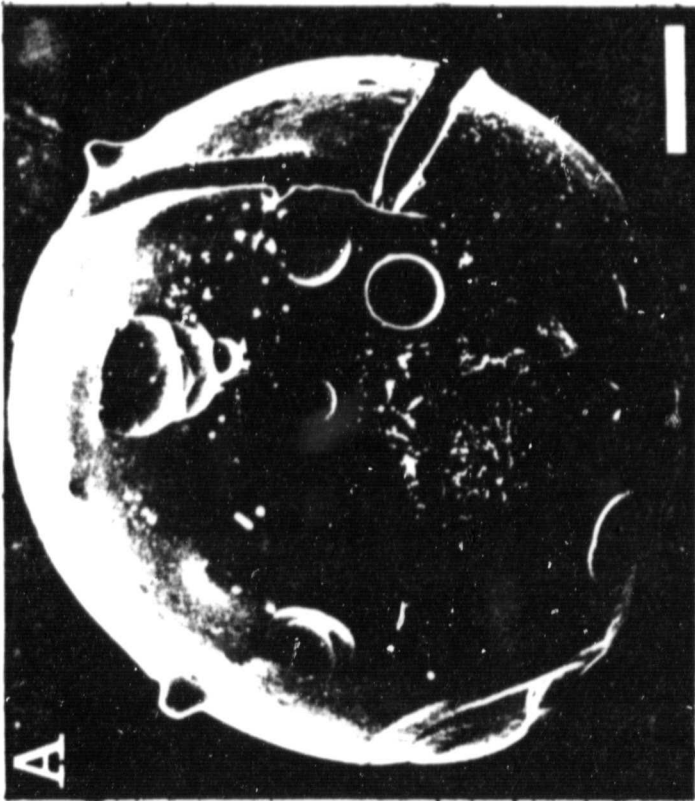
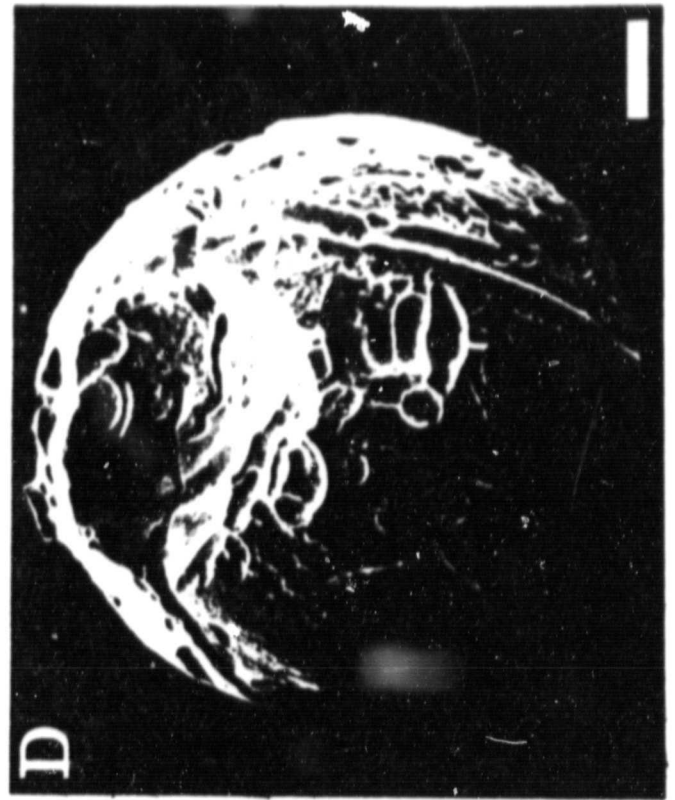
Figure 14. Average amount of solution of microtektites from selected sites versus water depth of coring sites.

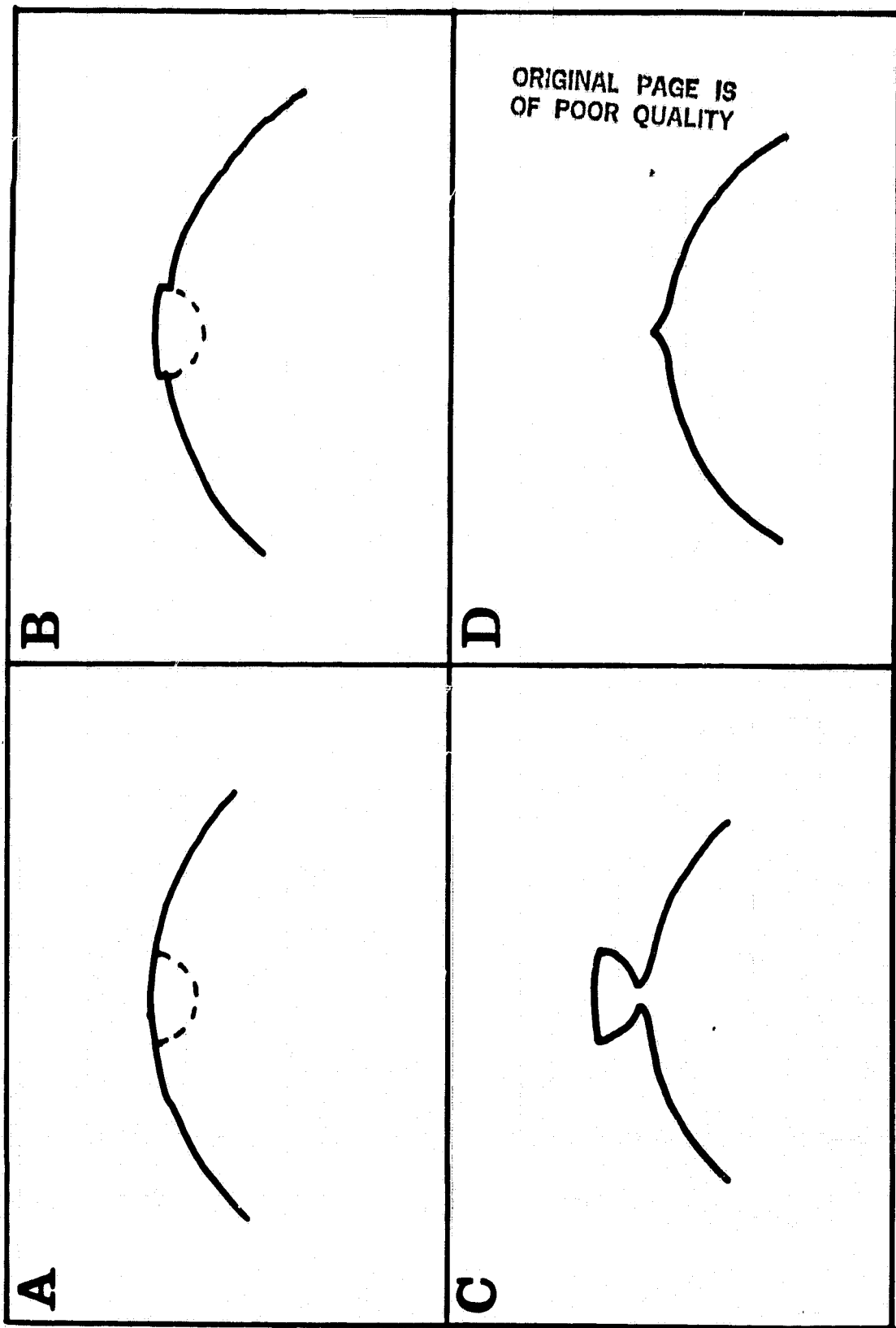
Figure 15. Average amount of solution of microtektites from selected sites versus sediment accumulation rates at those sites.



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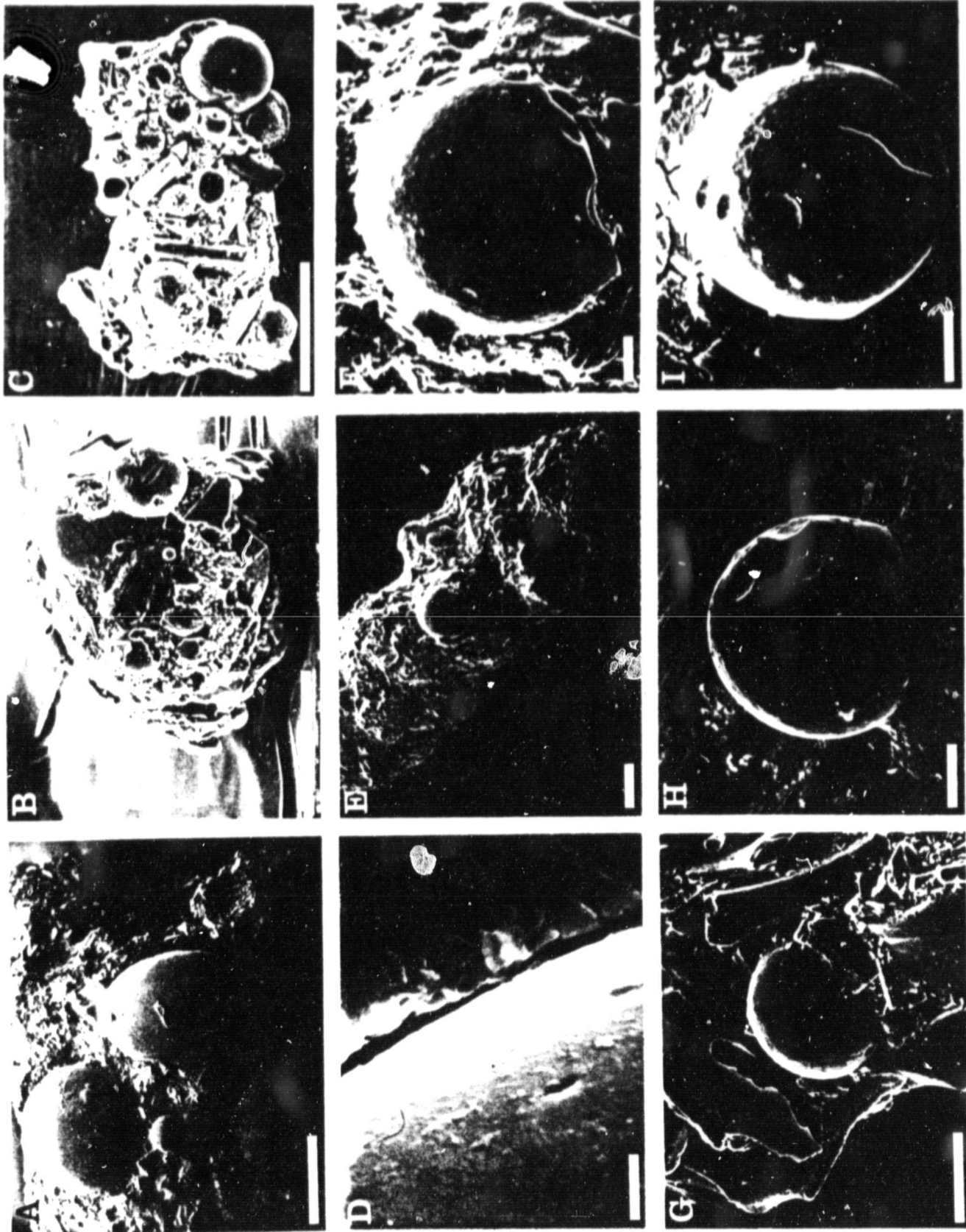






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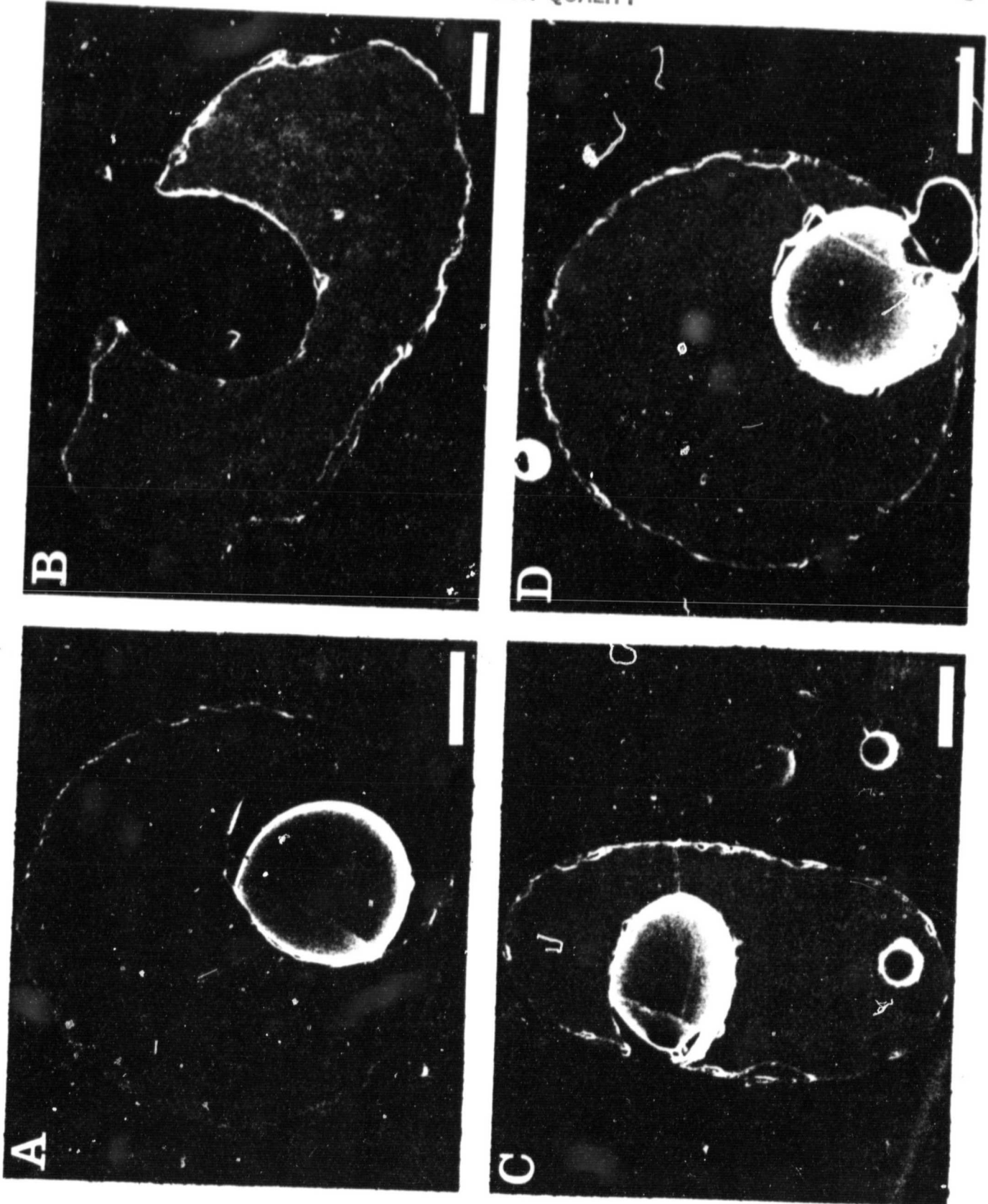


Figure 8

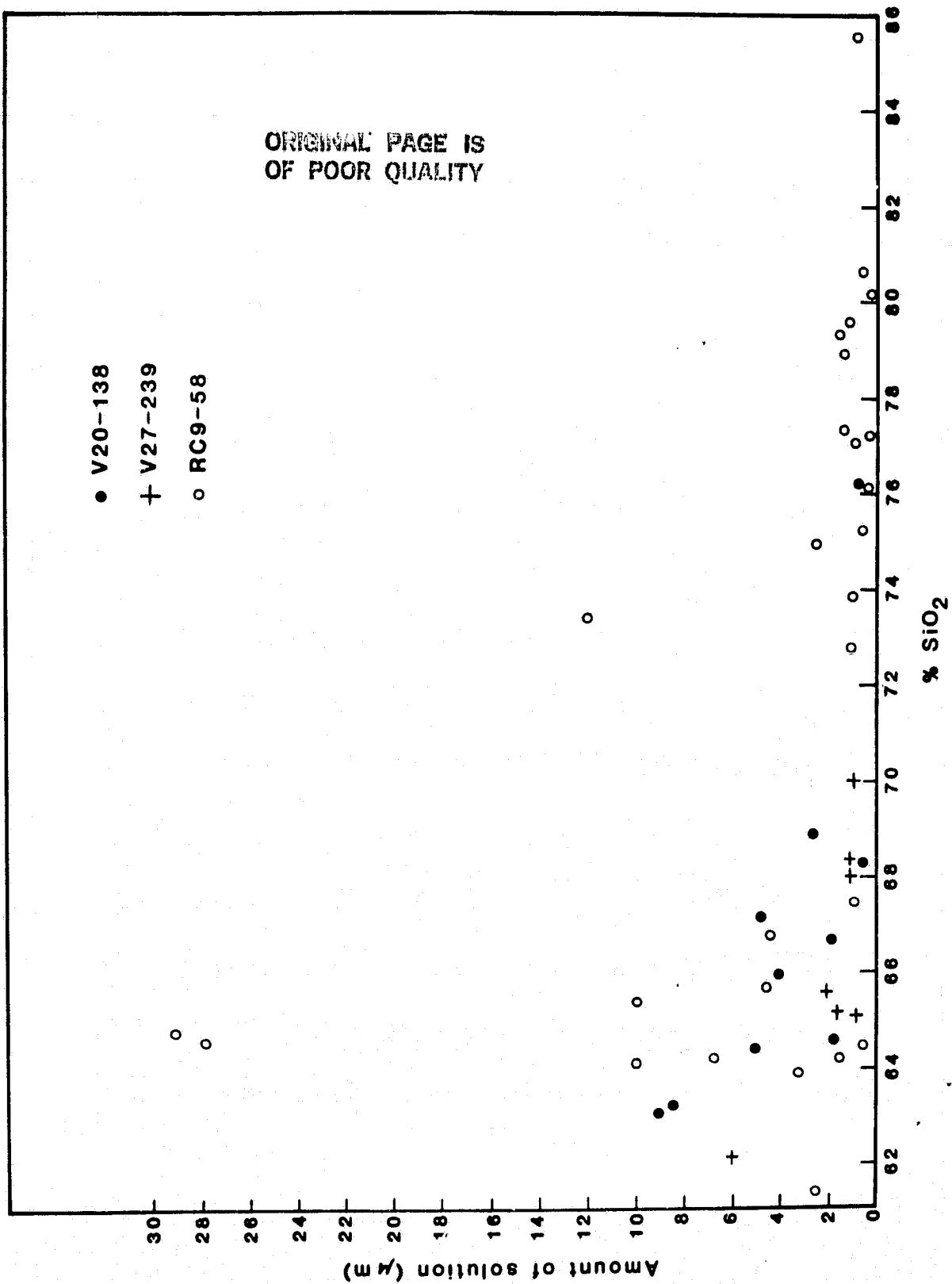


Figure 9

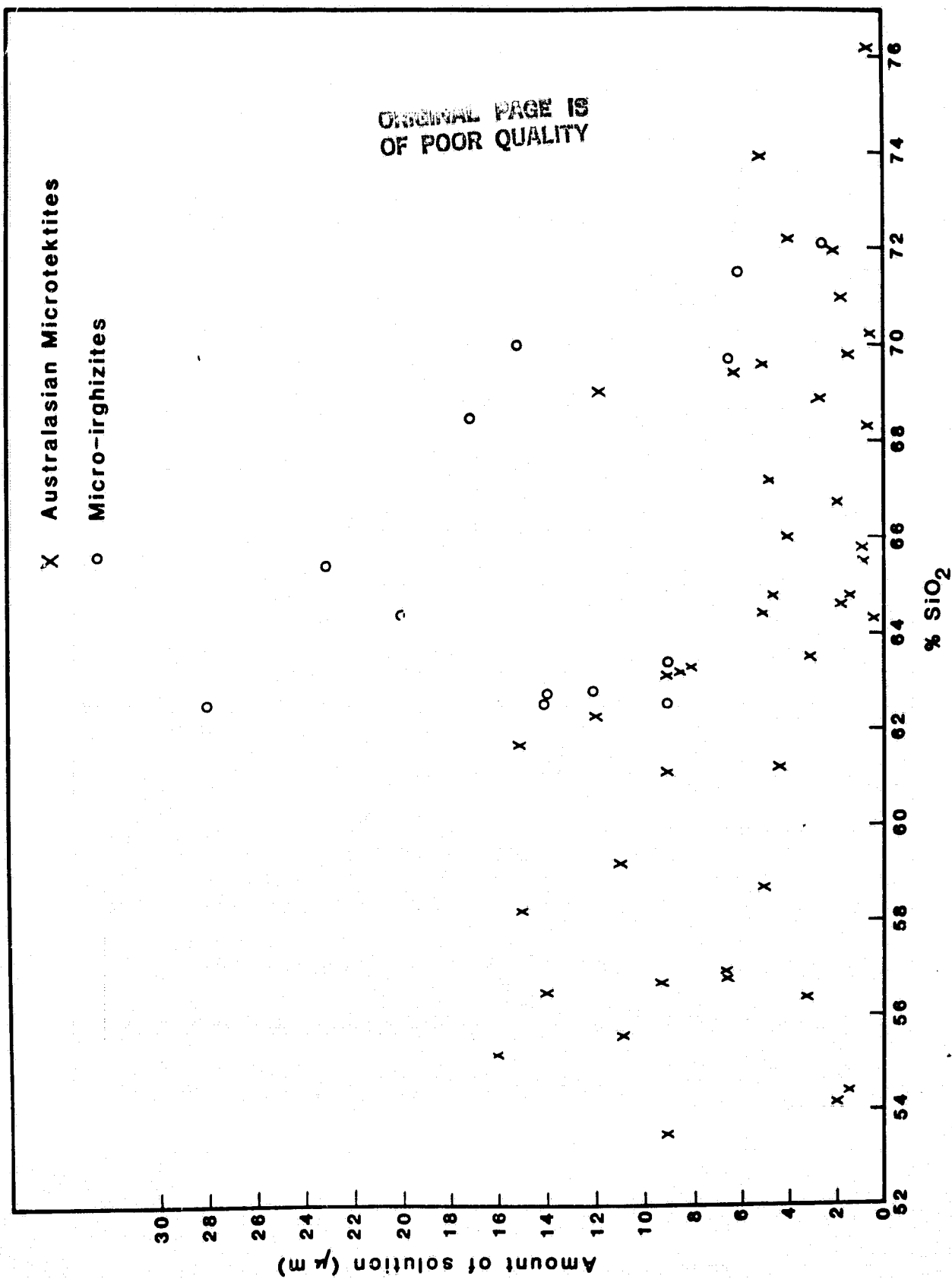


Figure 10

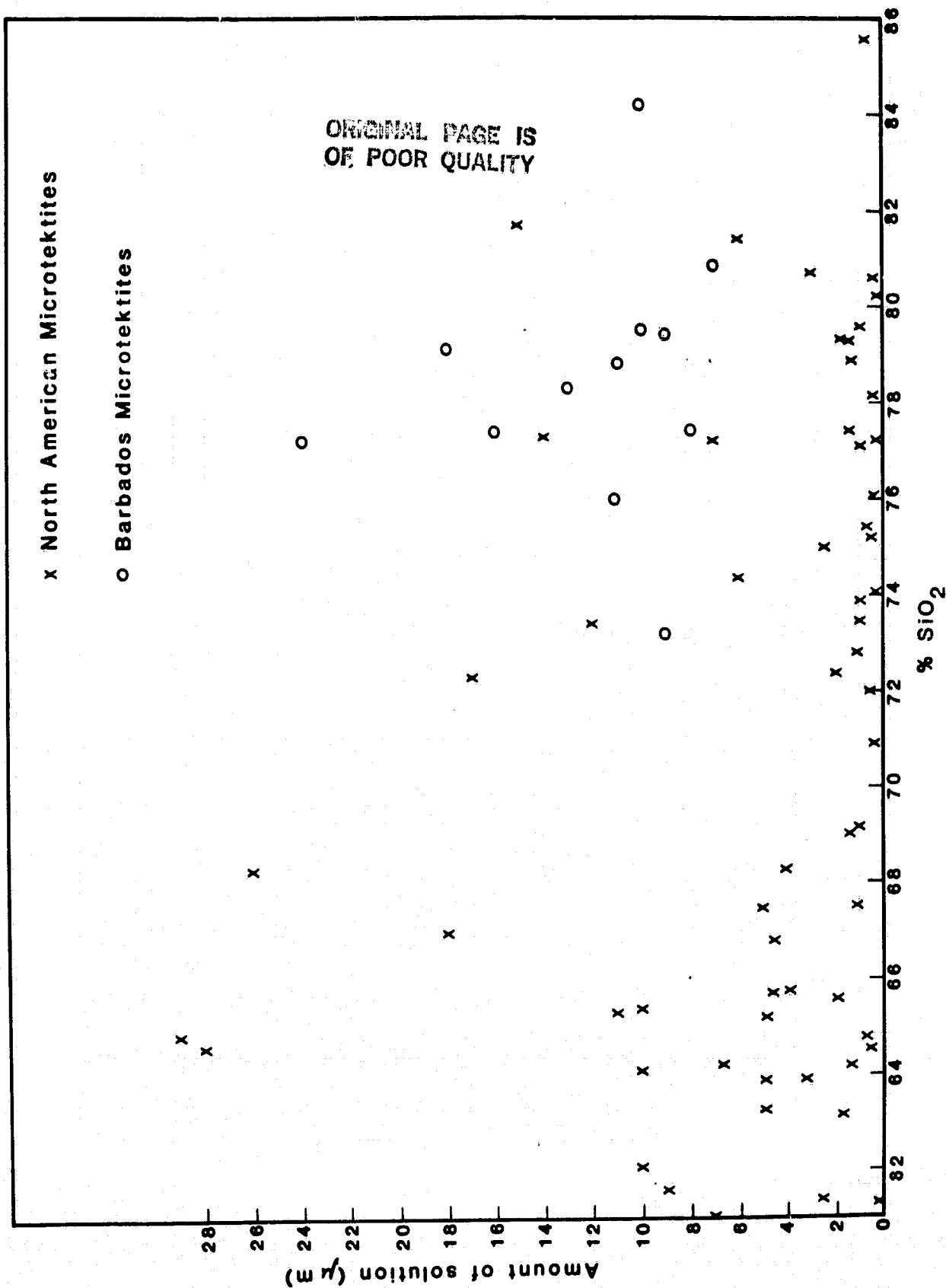


Figure 11

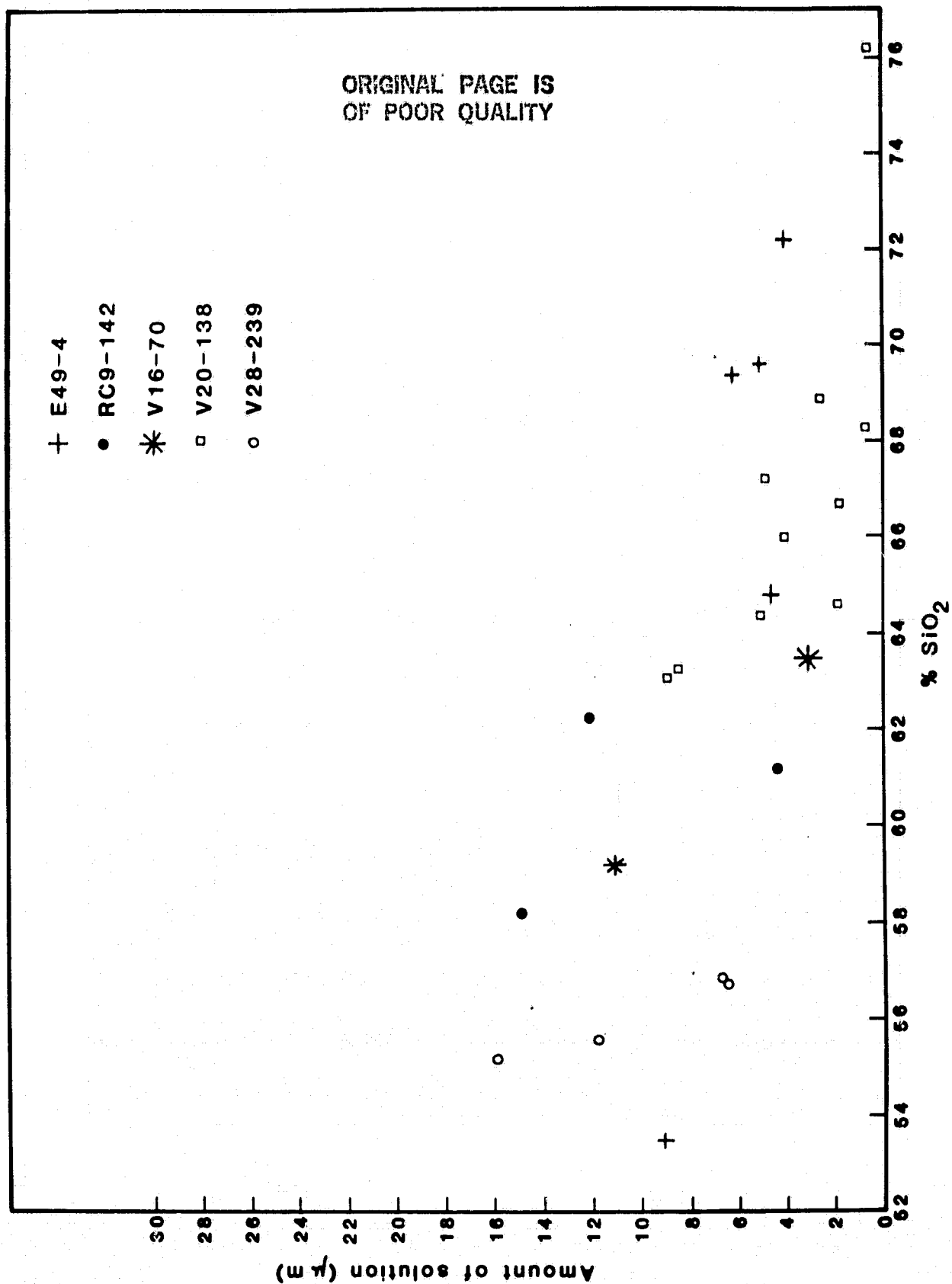


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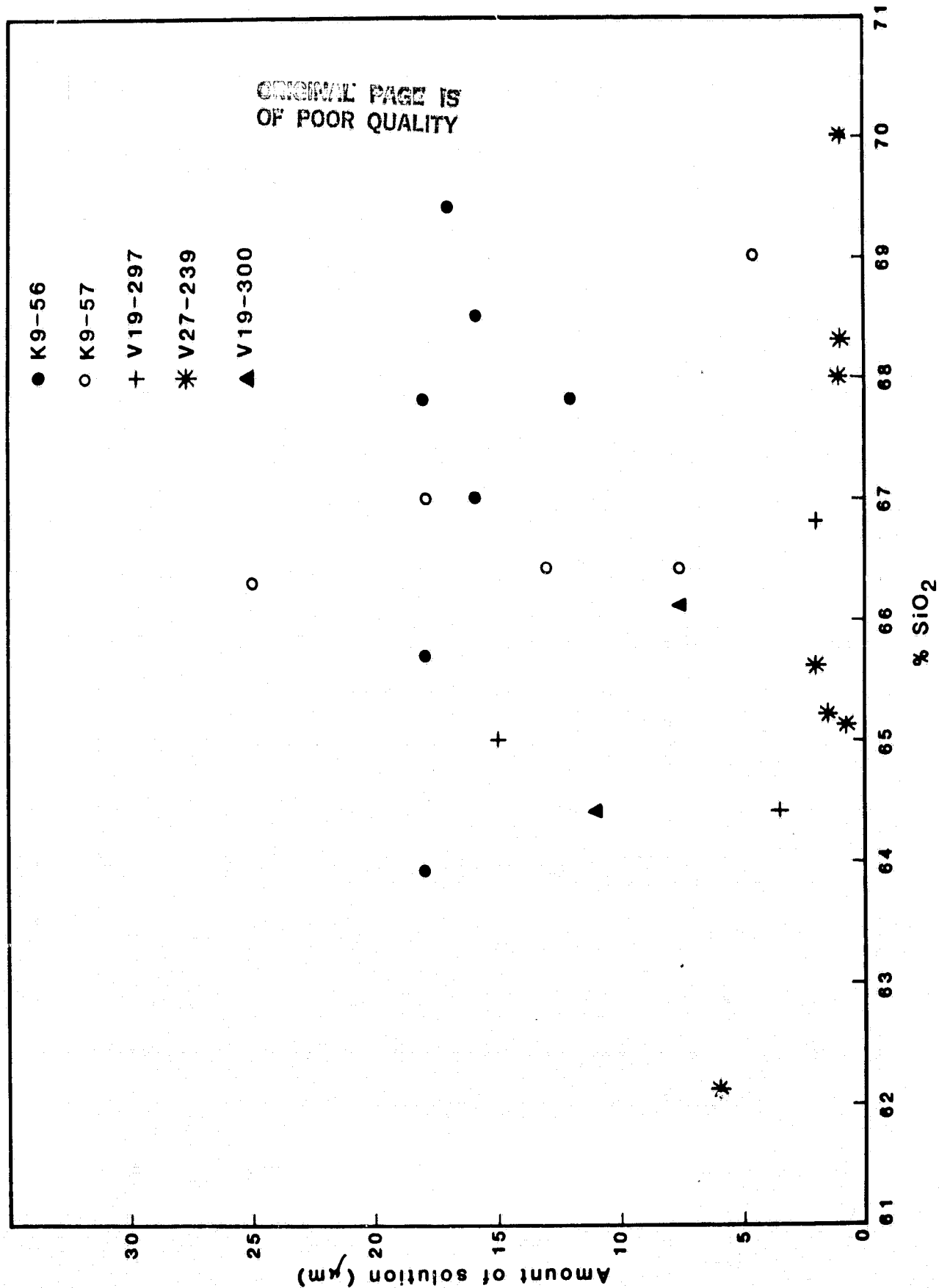


Figure 13

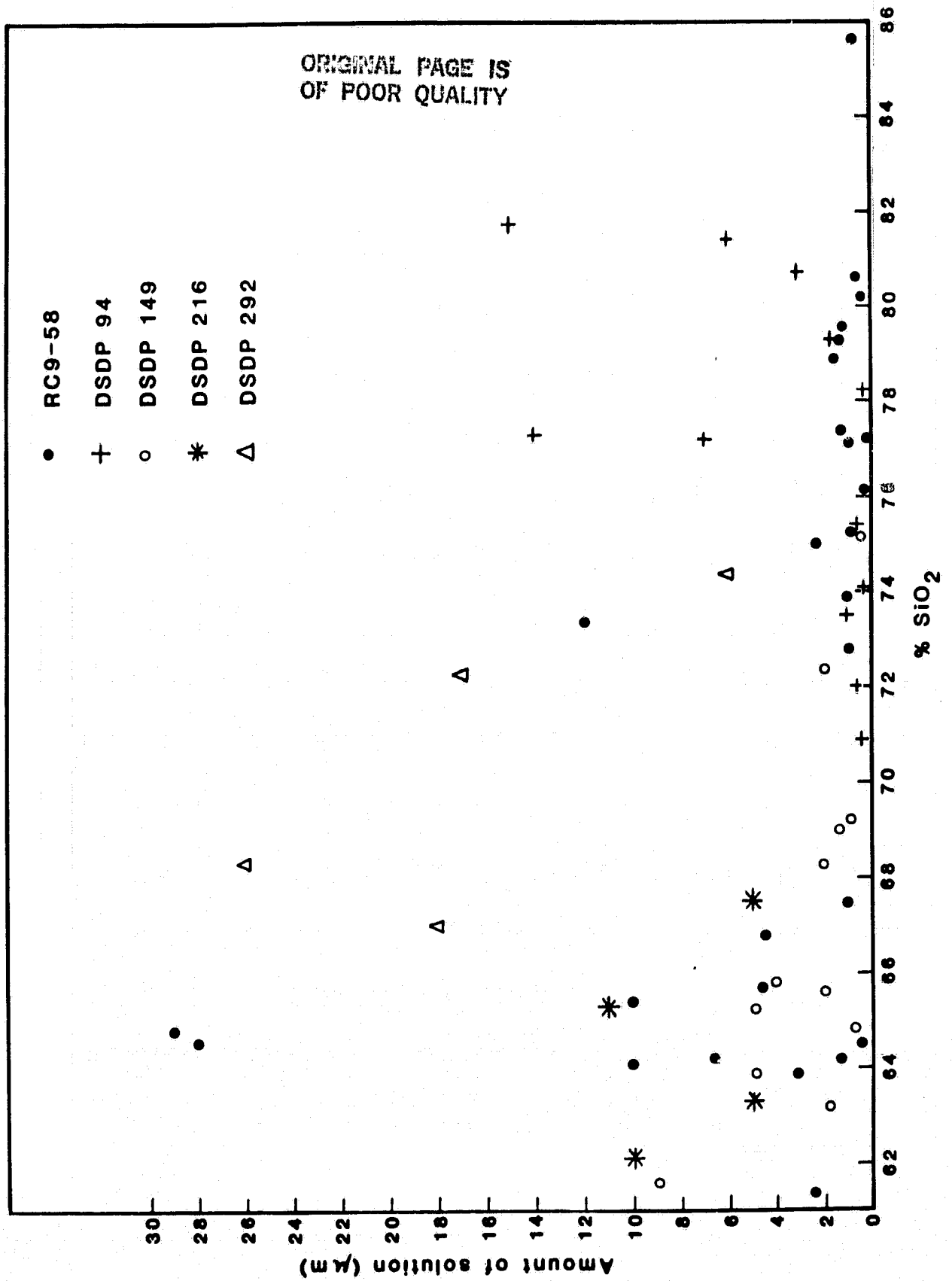


Figure 14

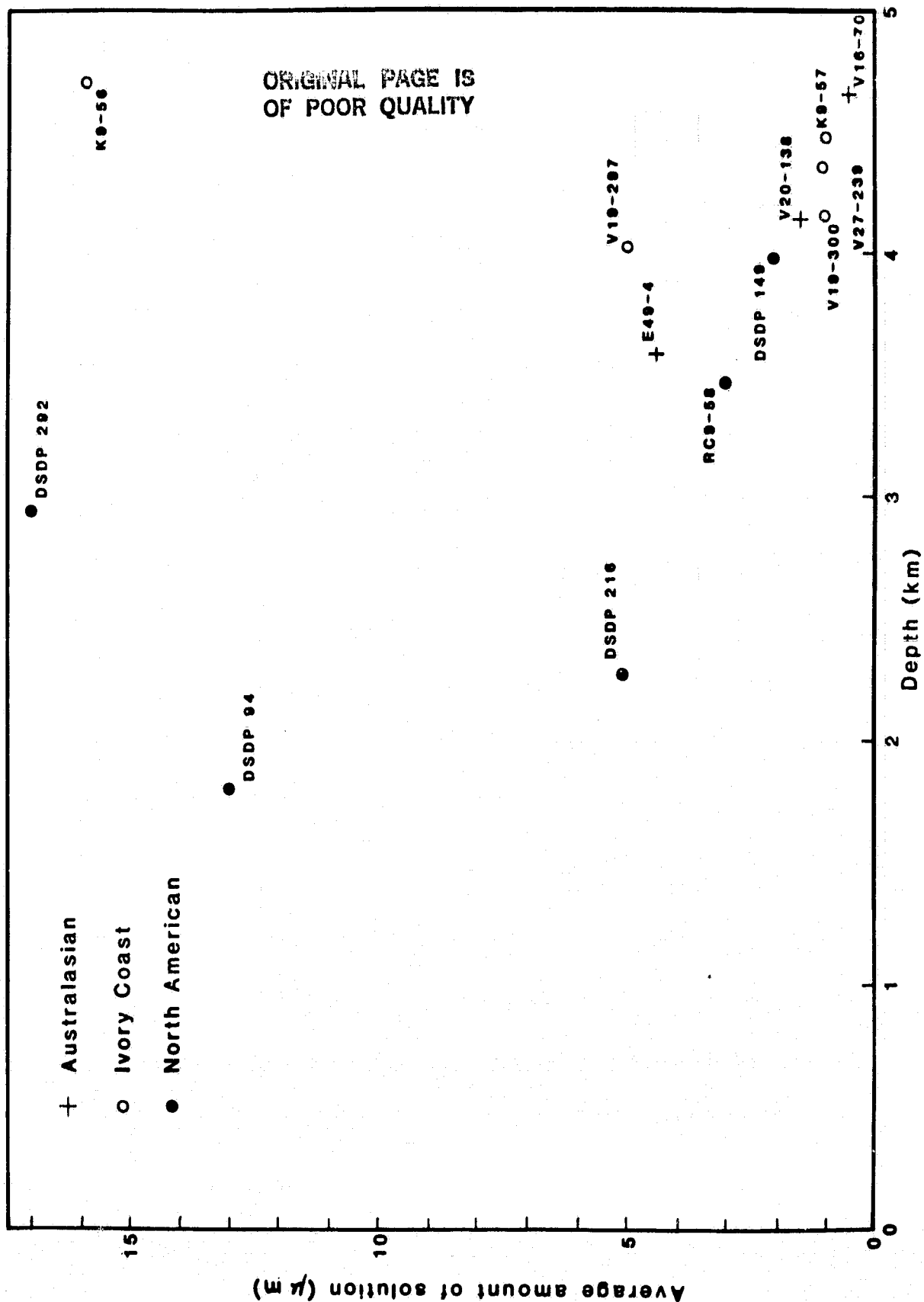


Figure 15

